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Hydrographical Conditions in the Southern North Sea during the Cold Winter of 1946-1947.

By

David Vaux,

Fisheries Laboratory, Lowestoft.

The winter of 1946-47 was particularly severe, with February the coldest for 50 years. To compare the severity of winters since 1900, use has been made of the data included in the Annual Ice Reports prepared by Dr. F. Nusser (1948, 1949) of the German Hydrographic Institute. Nusser uses two quantities to indicate the severity of the winter, "Eissumme" and "Kältewert". His "Eissumme" is the total number of days on which ice was observed at 20 selected positions along the German coast. The idea of "Kältewert" was evolved to take into account the effect of air temperature in the formation of ice, and is the product of the mean temperature of a "cold period" and its duration in days. A cold period ("Kälteperiode") is defined as existing when the air temperature falls below +0·5°C.

Nusser points out that although the winter of 1939-40 was the coldest on record, the amount of ice along the coasts was greatest in 1946-47. He attributes this to the relative lengths of warm- and cold-air periods, and to the existence of a layer of low-salinity water overlying more saline water along the Dutch and German coasts, this situation being brought about by easterly winds.

Figure 1 shows the values of "Eissumme" and "Kältewert" for each winter since 1900, the two values agreeing fairly well. It will be seen that, of the six coldest winters on record, three were war years for which hydrographical and biological observations are lacking. The cold winter of 1929, similar in many ways to that of 1947, has been described by Lumby and Atkinson (1929) together with the biological events. Dannevig (1930) has written of the effects of the cold period in 1924 in Norwegian waters, and the effects of low temperatures during 1947 in a limited area in the vicinity of the Isle of Man are described by W. C. Smith (1948). Simpson (1953) deals with the biological aspect of the 1946—47 winter in the North Sea.

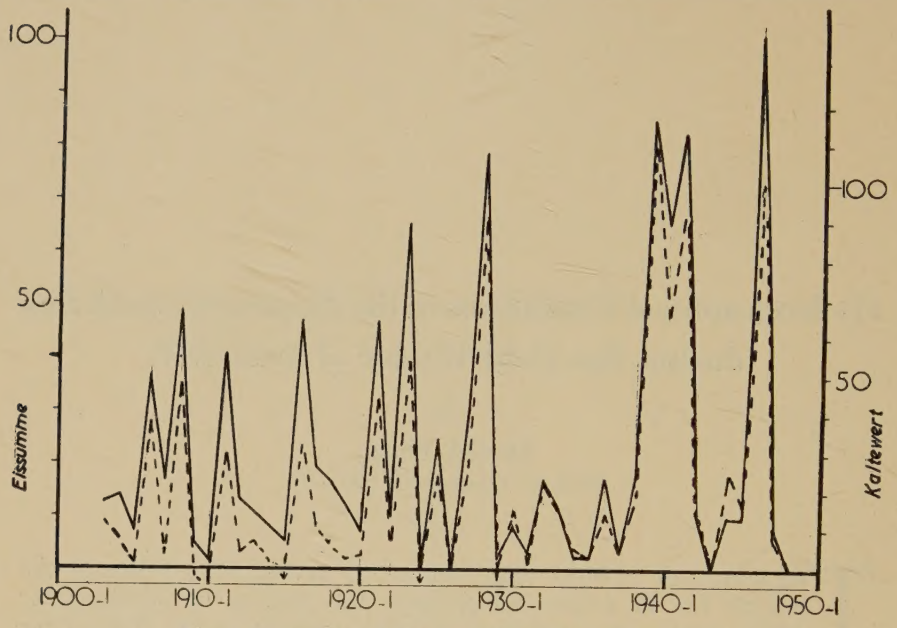

Figure 1. Severity of winters, 1903—04 to 1948—49.

The Meteorological Conditions.

During the second half of January 1947, the intensification of the high pressure system existing over the continent gave rise to strong easterly winds which swept across the North Sea. In the February Monthly Supplement to the *Daily Weather Reports*, published by the Meteorological Office, it was stated that "The east to north-east winds which set in on the 22nd January lasted without a break over most of the country until the 23rd February giving one of the longest (if not actually the longest) spells of east winds ever recorded in this country."

Observations of wind strength and direction usually made four times daily at the following seven meteorological stations around the North Sea have been examined:—

Tynemouth	55°01′N.,	01°25′W.
Spurn Head	53°35′N.,	00°07′E.
Gorleston	52°35′N.,	01°43′E.
Manston	51°21′N.,	01°22′E.
Den Helder	52°58′N.,	04°45′E.
Norderney	53°42′N.,	07°10′E.
Blaavandshuk	55°33′N.,	08°05′E.

Although varying considerably in strength and direction during the four months January to April, the winds at individual stations at any particular time were similar, and it has been thought unnecessary to show the observations at individual positions. Figure 2 shows the average of these

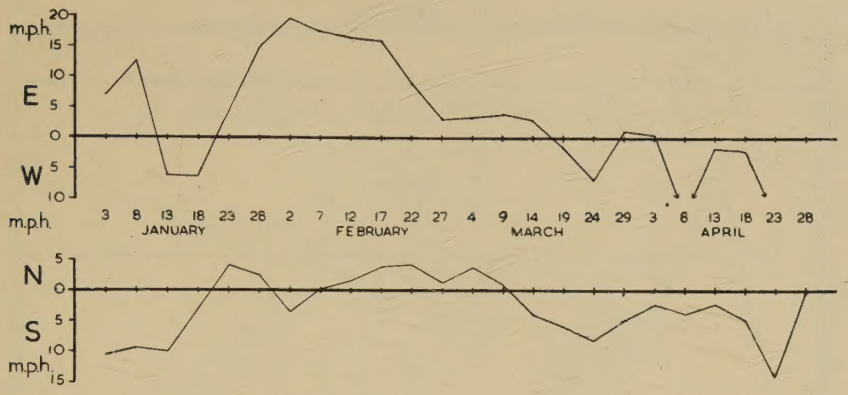

Figure 2. Winds over the North Sea, January—April, 1947.
Five-day means of recordings at seven stations.

observations in the form of their components, and indicates the duration of the easterly winds. The relation between winds and air temperatures recorded at these meteorological stations has been examined; as might be expected, low temperatures were associated with east winds, and higher temperatures with winds from the south-west. The fall in air temperature was followed quickly by a lowering of sea surface temperatures over the whole region. This effect is shown in Figure 3 in which simultaneous measurements of air and sea temperatures at the following five lightvessels have been plotted for comparison:—

"Vyl"	55°25′N.,	07°34′E.
"H. R. 1"	55°19′N.,	06°28′E.
"Pit Buoy"	54°19′N.,	04°30′E.
"Elbe 1"	54°00′N.,	08°11′E.
"Smith's Knoll"	52°43′N.,	02°18′E.

The last graph in the group shows the sea temperature at "Smith's Knoll" lightship with the air temperature at Gorleston, just over 20 miles from the lightship. It will be noticed that the water reached its minimum temperature progressively later from east to west. The water temperature began to rise once again about 15. March; this rise was general over the whole area, and coincided with the change from easterly to westerly winds and the movement of warm air fronts from the south-west across England.

Sources of Data.

The data available for an investigation of hydrographical conditions in the southern North Sea during the five months December 1946 to April 1947 consist mainly of observations made on the following ten voyages of the research vessels "Sir Lancelot" and "Platessa", the former operating on one occasion in company with H. M. S. "Mariner".

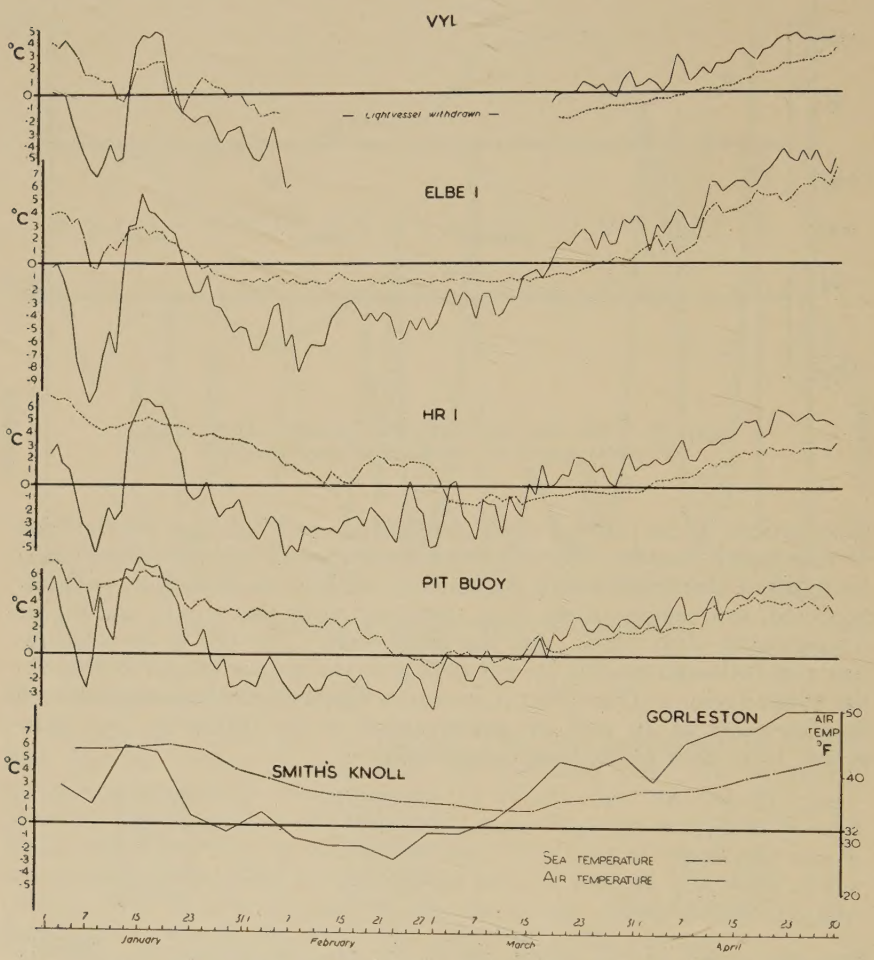

Figure 3. Air and sea temperatures at lightvessels in the North Sea, January—April 1947.

Sources of data

	Cruise	Date
"Sir Lancelot"	1946/II	26.—31. December
"Platessa"	1947/I	8.—12. January
"Sir Lancelot"	1947/I	9.—12. January
»	III	24.—29. January
H.M.S. "Mariner"	I	24.—27. January
"Platessa"	III	22.—25. January
"Sir Lancelot"	IV	13.—20. February
»	V	27. February—2. March
»	VI	11.—15. March
»	VII	22.—28. March
»	IX	14.—20. April

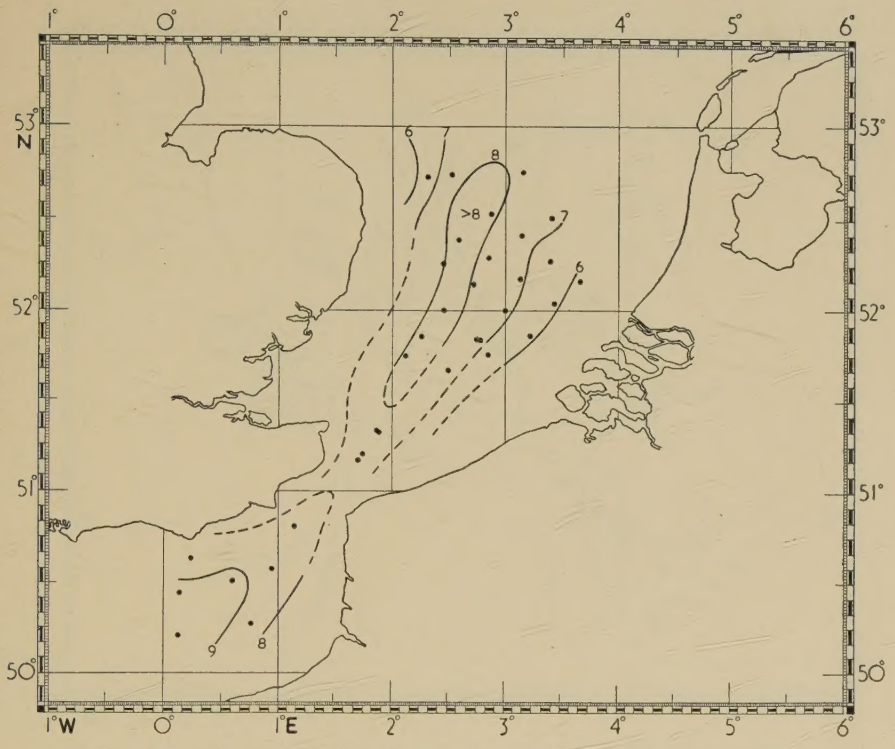

Figure 4. Distribution of surface temperature, 26.—31. December 1946.

The observations of temperature and salinity made on these cruises, together with those from the English lightvessel "Smith's Knoll", have been published in the *Bulletins Hydrographiques*. Data from the "Vyl" lightvessel, now published in the *Nautisk-Meteorologiske Årbog* for 1947 (Copenhagen, 1949), were kindly supplied before publication by the Danish Meteorological Institute.

Daily means of temperatures at "Elbe 1" and "H. R. 1" lightvessels were prepared from data listed in the *Deutsches Meteorologisches Jahrbuch*, Britische Zone, 1947, Part IV. Similar data, unpublished, for the "Pit Buoy"[1]) lightvessel were obtained from the German Hydrographic Institute through the kind co-operation of Dr. J. N. Carruthers. Acknowledgment of these data is gratefully made.

Distribution of Temperature and Salinity during the Winter.

Figure 4 shows that the form of the temperature distribution during the last six days in December was normal, with values about 1° lower than average for the time of year. The salinity was considerably higher

[1]) This lightvessel, maintained by Germany, is more commonly referred to in English as the "Pit" lightvessel. In this report the German name is used.

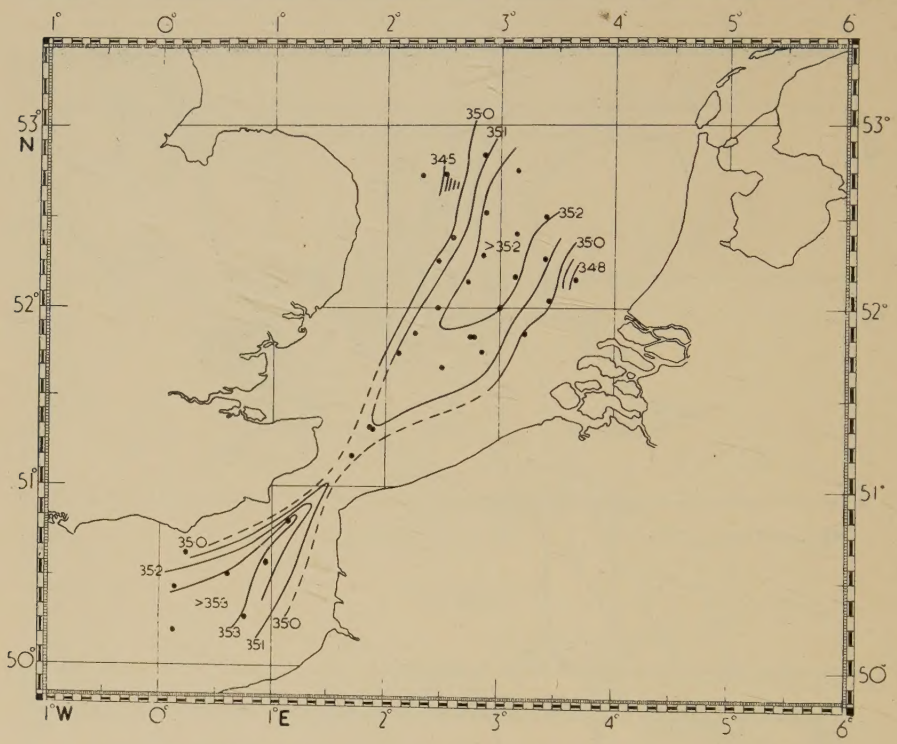

Figure 5. Distribution of surface salinity, 26.—31. December 1946.

than usual, probably as a result of a relatively strong influx of salt water from the English Channel in the previous few months. (Monthly means of temperature and salinity used for comparison are those of Böhnecke and Dietrich (1951), and the International Council (1933) respectively.) Figure 5 shows that there was an isolated body of water having a salinity greater than 35·2 ‰ in the centre of the Southern Bight and another body of water in the eastern English Channel with salinity exceeding 35·3 ‰.

By 9. January, this more saline water appears to have moved into the centre of the Southern Bight under the influence of winds which were predominantly south-westerly during the period 22. December to 4. January (Figure 6). Such a movement would mean that this water had travelled about 90 miles in 11 days, i.e., about 8 miles per day. A study of the currents through the Straits of Dover has led Carruthers, Lawford, and Veley (1950) to the conclusion that the surface current measured from the "Varne" lightship by the use of the Vertical Log current-meter is of the order of $1^1/_2$ % of the wind travel. The mean wind of 23 miles per hour which, on the above estimate, would produce a current of 8 miles per day through the Straits was not experienced. An examination of the synoptic weather

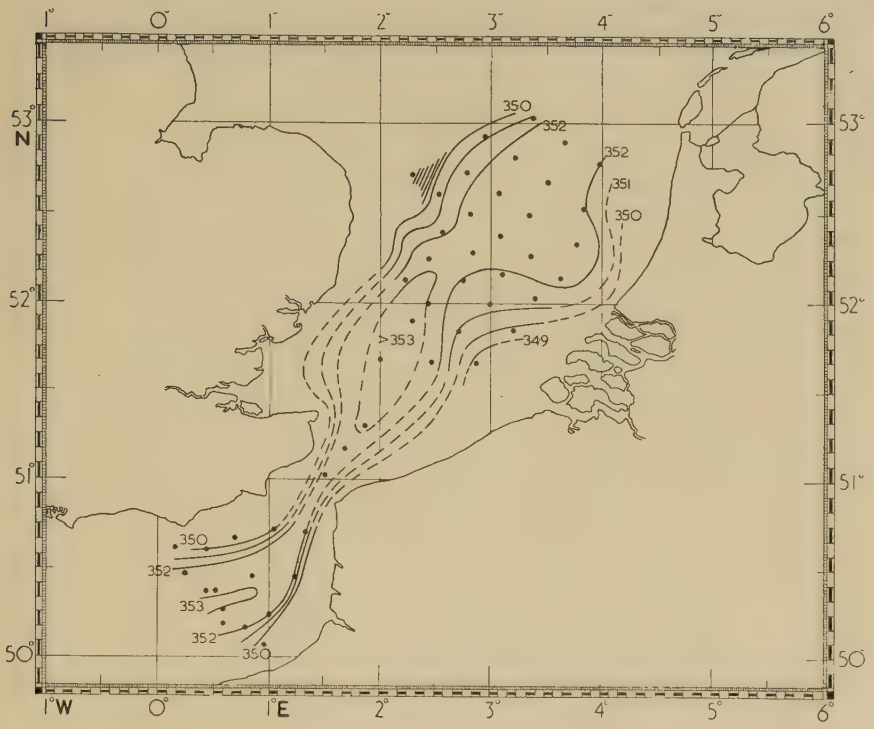

Figure 6. Distribution of surface salinity, 9.—12. January 1947.

charts for this period indicates conditions approaching those which Carruthers (1930) considers favourable to strong east-north-east-going currents through the Straits of Dover. The chart for 3. January shows that a very deep depression was present west of Iceland, pressure was high over the continent, and winds over the whole of the North Sea were mainly from the south. This qualitative picture seems to fit the circumstances better than an estimation of currents made from the local wind in the vicinity of the Straits. It is therefore probable that there had been a considerable movement of water from the English Channel into the Southern Bight.

Some cooling of the sea occurred between these first two cruises, this being the first sign of the extreme conditions to follow.

The third of the surveys began at the time of the onset of the period of persistent easterly winds. Figures 7 and 8 show the temperature and salinity distributions at the time. Apparently there had been a further cooling of the area; the water in the German Bight was then 1° to 2°C. below the average for the time of year, and 2·5°C. below average at the "Vyl" lightvessel.

By the middle of February, water conditions in the southern North Sea had been markedly changed by the now strong easterly winds and

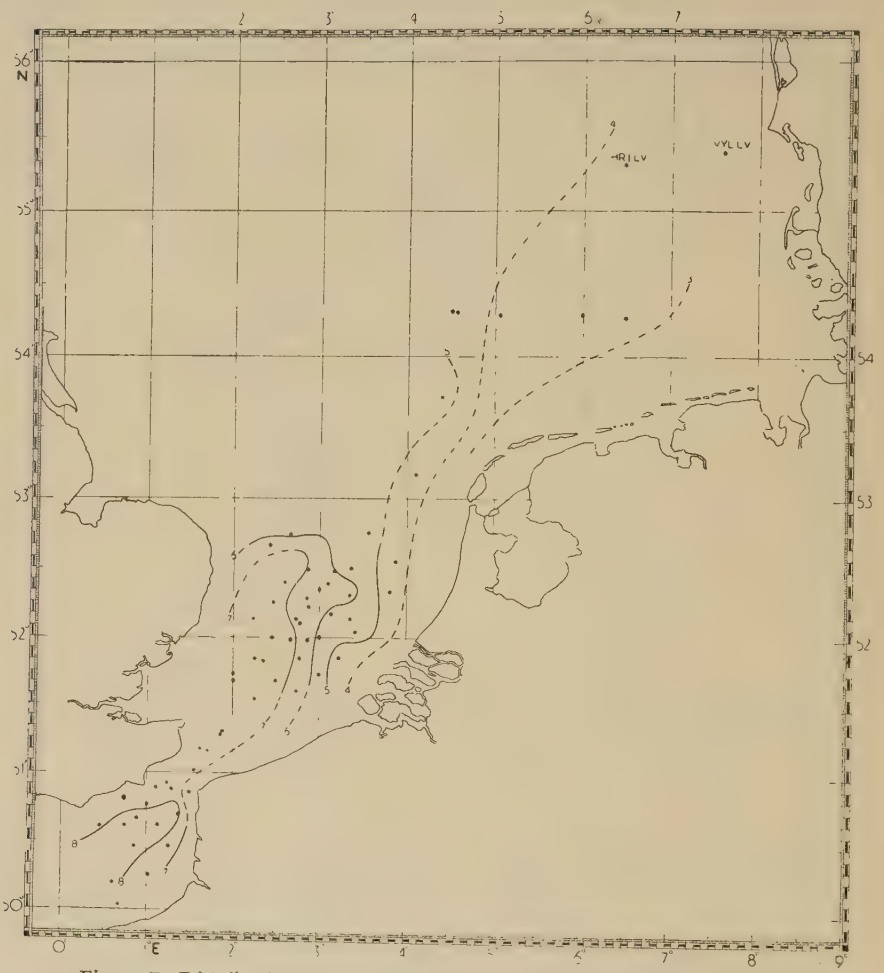

Figure 7. Distribution of surface temperature, 24.—28. January 1947.

the low air temperatures. Sea temperatures recorded were as low as —1·8°C. and pancake ice was observed from the "Sir Lancelot" over a wide area some 25 miles off the Friesian Islands. This ice was composed of pieces up to sixty feet long and a foot thick, and showed signs of having been formed near land. It extended as far south and east as the eye could see, with lanes of clear water running through. Over a still larger area the sea surface had a greasy appearance due to the freezing of the surface water into slush. Surface conditions changed considerably during the survey, and observations made on the outward and homeward runs cannot be combined. Figures 9 and 10 show conditions between 16. and 18. February. Considerable differences between surface and bottom temperature and salinity were recorded where previously the water column had been homogeneous.

Figure 8. Distribution of surface salinity, 22.—28. January 1947.

On the following cruise, ten days later (28. February; Figure 11), the cold water was again found at the surface, although by this time it was beginning to disperse and mix with the warmer water below, causing a return to the more usual structure. The average difference in temperature between surface and bottom at five stations had been reduced to 0·1°C. Observations made on the research vessel indicated that the wind had dropped to about Beaufort force 4 and observations on land at the English and continental meteorological stations showed a change in the prevailing wind system.

During the second week in March another survey was made in the Southern Bight. Isotherms had a normal form, but temperatures generally were about 4° lower than the average March values (Figure 12). The salinity of a small patch of water was as high as 35·4 $^0/_{00}$, an increase of 0·1 $^0/_{00}$ on the February value (Figure 13). The winds during this period were unfavourable to any such drift from the English Channel as might have caused a rise in salinity.

Sea temperatures generally began to rise after the middle of March, and the few observations made between 24. and 28. March showed that the surface water was already a little warmer than the bottom water. Water temperature continued to rise throughout April, during which month winds from the south-west predominated.

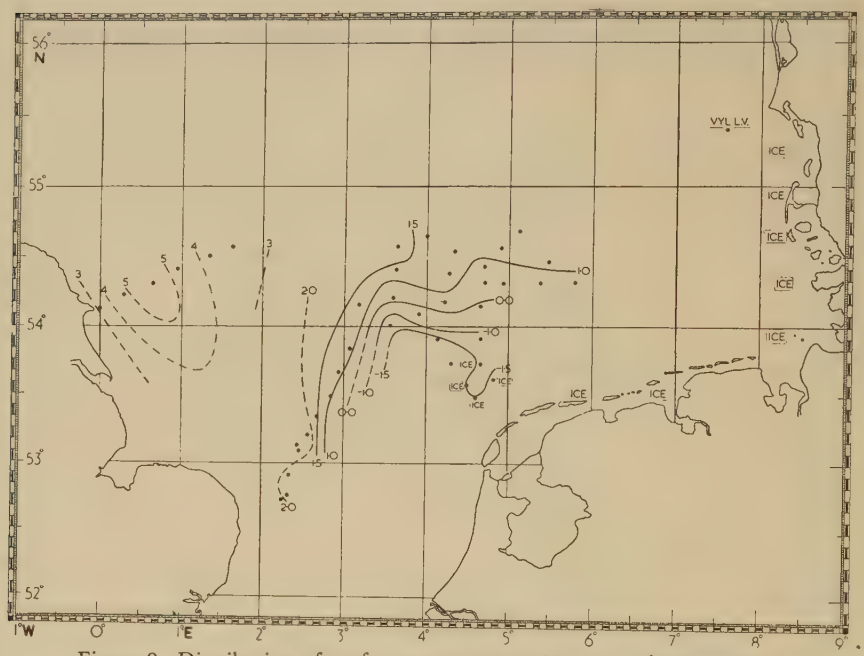

Figure 9. Distribution of surface temperature, 16.—18. February 1947.

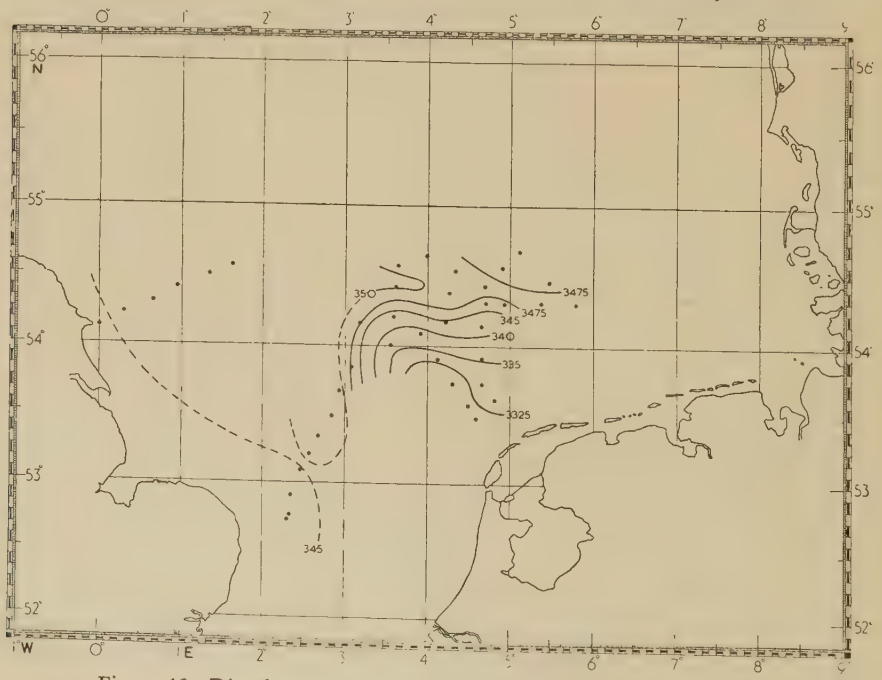

Figure 10. Distribution of surface salinity, 16.—18. February 1947.

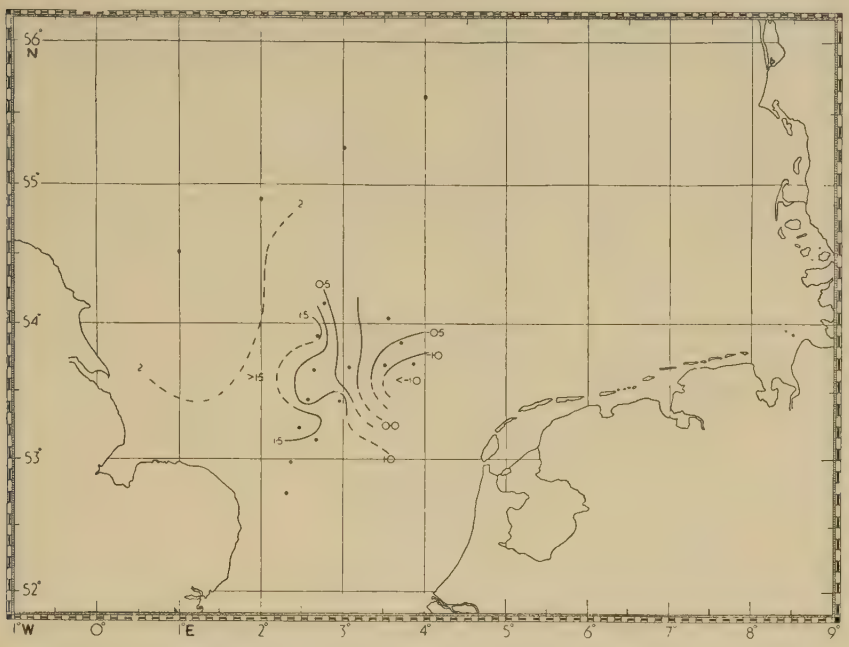

Figure 11. Distribution of surface temperature, 27. February—1. March 1947.

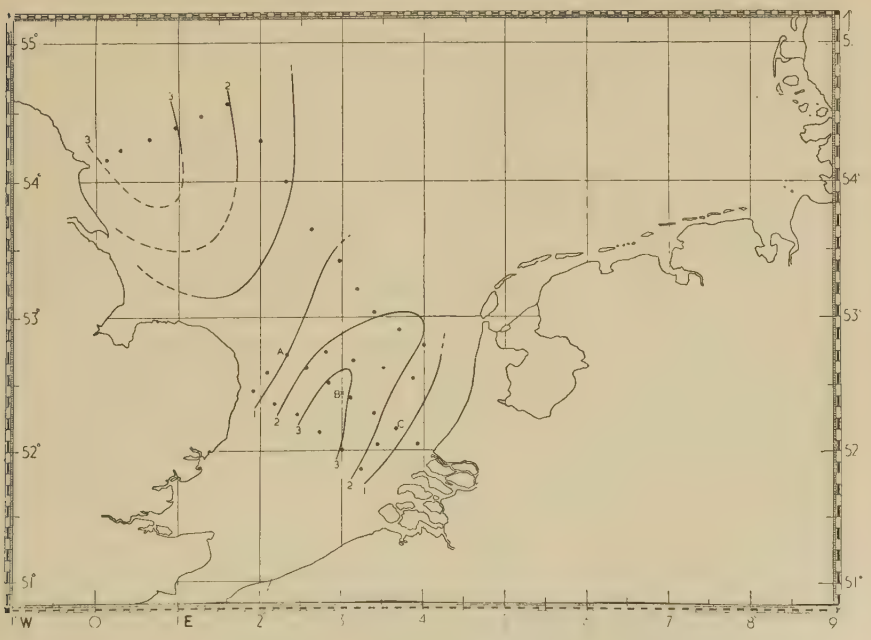

Figure 12. Distribution of surface temperature, 11.—14. March 1947.

Figure 13. Distribution of surface salinity, 11.—14. March 1947.

The Minimum Temperatures reached.

In view of the biological implications, it is of interest to know the lowest temperatures reached during the cold period, and also their duration. Some fifty miles north-west of the Friesian Islands the surface water was undoubtedly at its freezing point in mid-February (water of salinity 33·0 ‰ freezes at about —1·8°C.) but at the "Pit Buoy" lightvessel, the minimum surface temperature of —0·9°C. was not recorded until 1. March. The bottom water, considerably warmer than this, would be cooled by mixing with surface water until about 14. March by which time the temperature of the surface water had become positive as a result of the increase in air temperature. This process of mixing can be seen from the T-S diagrams. The bottom water in this region, then, probably fell to a minimum of 0°C. at about the middle of March. The greatest extent of water of zero temperature on the bottom, as far as can be judged from the few subsurface temperatures taken, would be about the same as that of the surface water below —1°C. shown in Figure 9.

Conditions in the Southern Bight, however, were different from those offshore from the Friesian Islands. The water in the Southern Bight was warmer at the onset of the cold period, and it is unlikely that there was any large quantity of cold water blown across from the Dutch coast. At "Smith's Knoll" the minimum surface temperatures of 1·3°C. were recorded on 12. and 16. March at about the time of one of

"Sir Lancelot"'s surveys. Figure 12, therefore, probably represents the distribution of temperature at its minimum. If cooling had been due to mixing with cold water from the east rather than to the low air temperatures, the minimum temperature would have been experienced a little earlier in the centre of the Southern Bight than at "Smith's Knoll". Figure 14 shows the variation of temperature at three positions (see Figure 12) in the Southern Bight on a line from "Smith's Knoll" to the Hook of Holland, together with "Smith's Knoll" data for

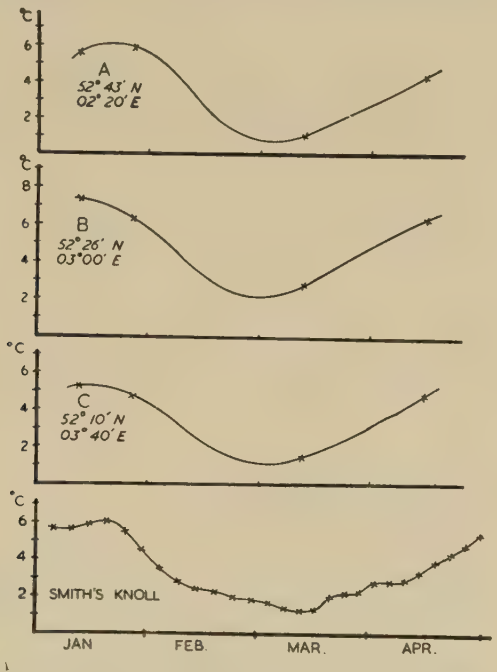

Figure 14. Variation of temperature at three positions in the Southern Bight and at "Smith's Knoll".

comparison. The minimum temperatures reached by the central and coastal water bodies and their duration have been estimated, it being thought that these minimum temperatures occurred just before, or possibly at the time of, the mid-March survey.

As cooling of the water was produced at the surface by the low air temperatures and by mixing with cold, wind-driven, light coastal water, the bottom water would probably be warmer than the surface water throughout the period, certainly not colder. There is no evidence, therefore, for negative or even zero temperatures in the Southern Bight either at the surface or bottom and such, in the writer's opinion, did not exist on any significant scale at any time during the winter.

The Temperature-Salinity Relation.

The use of T-S curves throws some light on the changes taking place during the cold winter. Instead of the more usual relation of temperature and salinity observations at different depths, surface observations

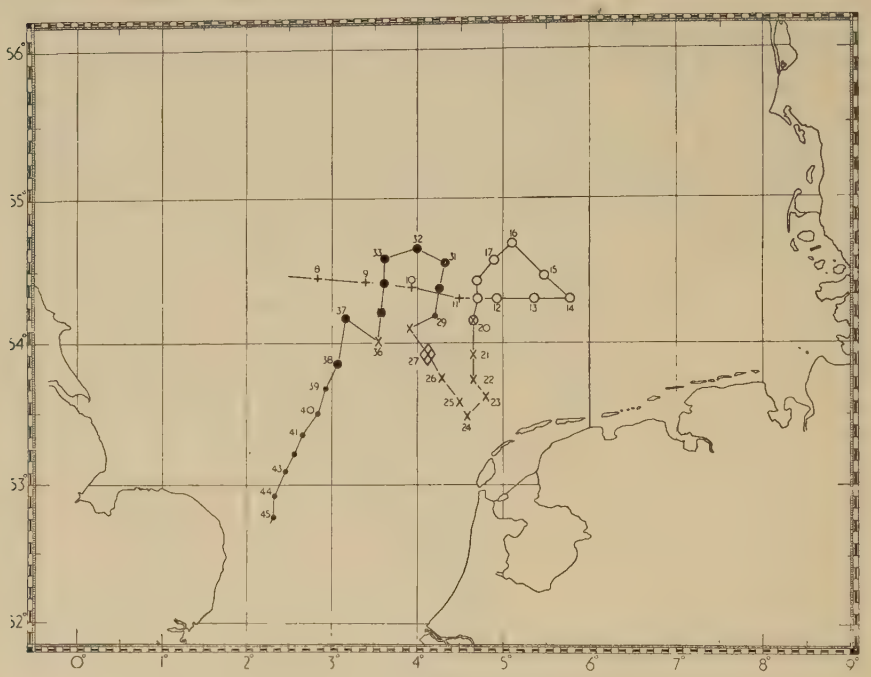

Figure 15. Stations worked by "Sir Lancelot" on Cruise IV.

at different positions from two surveys have been related by means of these curves (Figures 15 to 18).

The water in which the "Sir Lancelot" started making observations had a temperature of 2·0° to 2·5°C. and a salinity of 34·4 to 34·8 $^0/_{00}$ (stations represented by upright crosses). Water of about the same salinity but 1° colder was next encountered, eight stations being worked in this water-type (stations shown as circles). At the next station, water was found which was a mixture of the previous type and a new cold type having a low salinity (temperature below —1°C., salinity 33·0 to 33·5 $^0/_{00}$). Seven stations were worked in this type of water and these are shown by oblique crosses; at one station (27) a depth series of samples was obtained, this station being indicated by a cross within a diamond. The temperature and salinity values at these depths have been included in the surface T-S diagram (dotted line joining diamonds). Samples from 0, 11, and 20 m. showed that the upper layer of water was of the cold type, whilst samples from 30 and 35 m. (bottom) showed the existence of water made up of a mixture of the first two water-types. A sample from 35 m. at the previous station (26) indicated the presence of the warmer mixed water at the bottom. Observations made at the "Vyl" lightvessel just before it was withdrawn from station on 5. February (dashed line joining squares) show the presence of a similar cold water-type along the Danish coast. It is probable that water of similar characteristics extended along the coasts from the Friesian Islands for

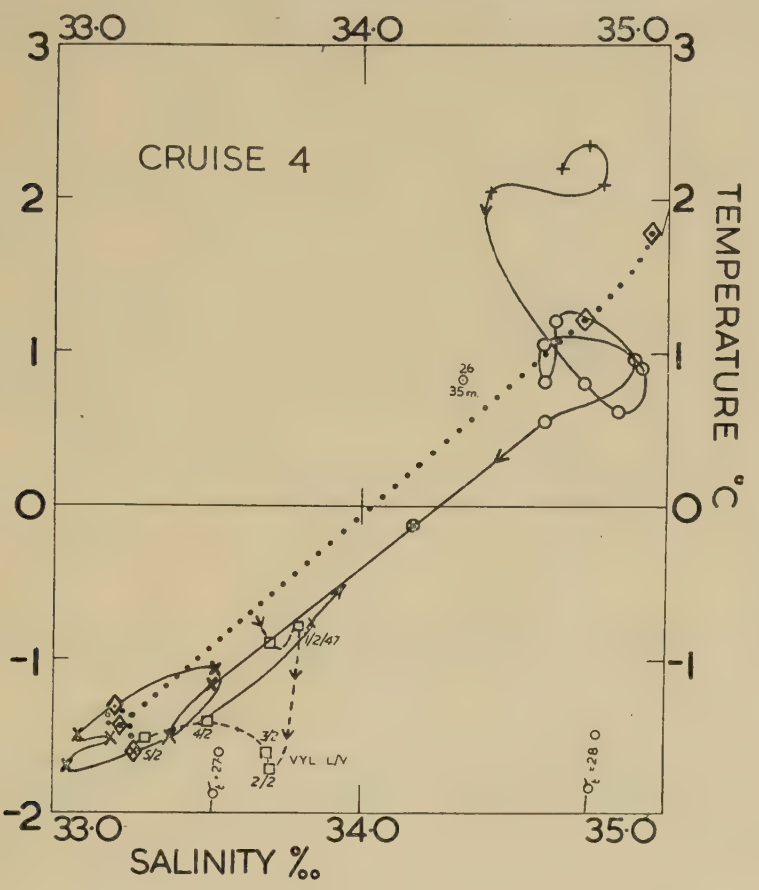

Figure 16. T—S diagram for Cruise IV of "Sir Lancelot".

an indefinite distance north of the "Vyl" lightvessel as was the case in 1929. It has already been mentioned that ice observed at sea appeared to have come from the coast.

The "Sir Lancelot"'s next survey (Cruise V) took place some distance to the west of the previous one, but at the most easterly stations (8, 9, and 10) water was found which was a mixture of the warm and cold types encountered a fortnight earlier. The straight line representing the mixed water of cruise IV has been reproduced (dotted) on the T-S diagram for cruise V, and the proportion of each water-type in the mixture at stations 8 and 9 can be seen. A water sample taken at the bottom (43 m.) at station 8 showed the warmer water-type still present and comparatively unchanged. At stations 10 and 11 there seems to be evidence of mixing with more saline water which could have come from the region to the south.

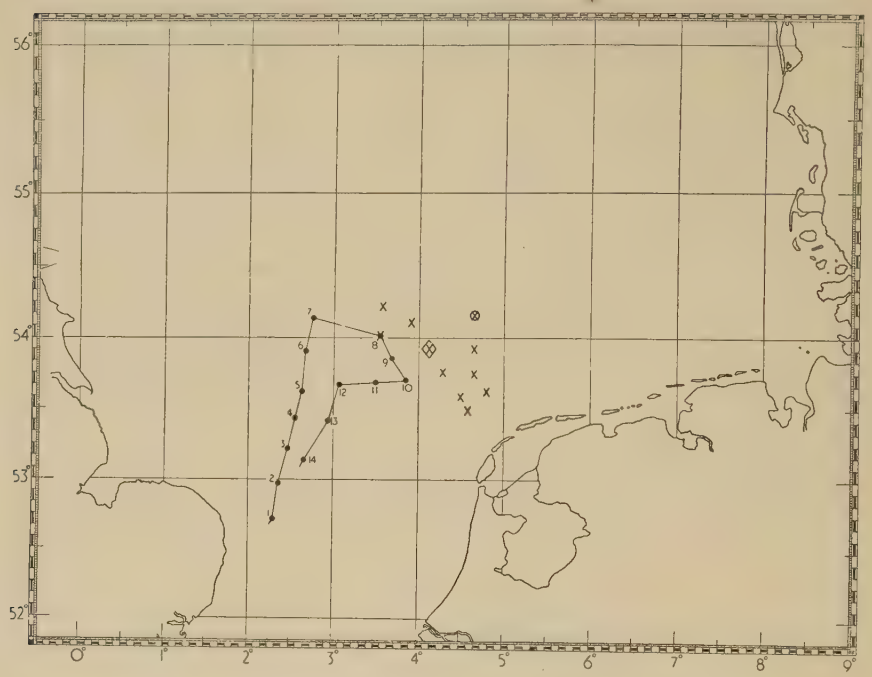

Figure 17. Stations worked by "Sir Lancelot" on Cruise V.

It appears from this examination that the cold water encountered was a wind-driven layer originating in the German Bight, and gradually spreading westward over the central North Sea. Such a movement would require a compensating current to be set up which might take the form either of an east-going bottom current in the central North Sea, or of an easterly movement of the total water column in the Southern Bight, or possibly both. Simpson (1953, p. 156) in fact, observed an easterly displacement of plaice eggs and larvae during the period, and although there are no hydrographical data to support this finding, it seems that this movement was at least a part of the compensatory mechanism.

The Salt Content of the Southern Bight.

Attention has already been drawn to the fact that the salinity of the water in the centre of the Southern Bight increased throughout the winter months. This could have been the result of a continuous flow of more saline water from the English Channel through the Straits of Dover or of evaporation over the area, or both. An attempt to separate these effects has been made.

It is a feature of the salinity distribution in winter that the central water body of comparatively high salinity is fairly homogeneous both horizontally and vertically, and is separated from the less saline water

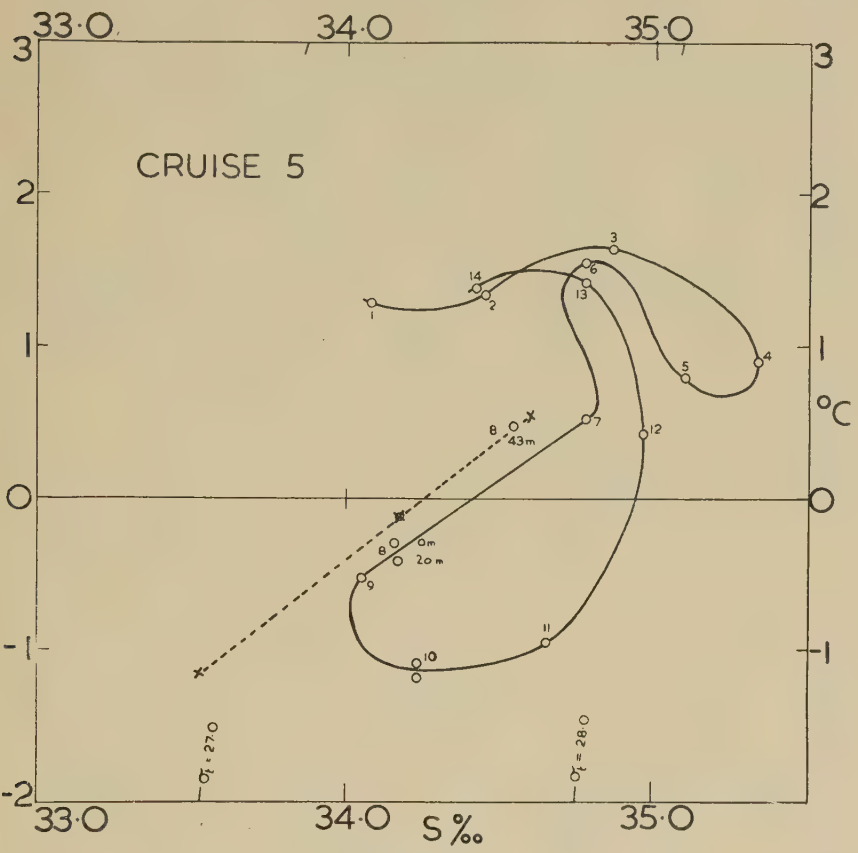

Figure 18. T—S diagram for Cruise V of "Sir Lancelot".

of the Dutch and English coasts by discontinuities, shown by steep gradients in salinity. Although vertical and lateral mixing takes place freely in the central water, it appears that there is but little mixing in the narrow bands of water lying between it and the coastal water. The discontinuity corresponds to the region of water having a salinity lying between 34 and 35 $^0/_{00}$. If we make the assumption, then, that no salt is lost across the 35 $^0/_{00}$ isohaline from the central water, it is possible to separate the factors, bearing in mind that evaporation will increase salinity without altering the total amount of salt present, whereas an influx of salt water would increase both simultaneously. Planimeter measurements were made on the contours of the salinity distribution to determine the amount of salt contained within the 35 $^0/_{00}$ isohaline during each survey. As it was not possible to close this isohaline to the north and east, the region is bounded on the north by latitude 53°N. and on the east by longitude 4°E. This detracts a little from the certainty of the conclusions. The computations are set out in Table 1.

Table 1.

Salt Content of the Area bounded by the 35‰ Isohaline in the Southern North Sea, December 1946—March 1947.

Period of Survey	Isoline chosen ‰	Mean S‰ contained within chosen region	Area of region sq. miles	Wt. of salt contained in region tons	
26.—31. December 1946	35·2	35·23	1,548·4	$5{,}140{\cdot}8\times10^6$	
	35·1	35·15	1,665·4	5,483·6	Total salt = 14 thousand million tons
	35·0	35·05	1,153·4	3,809·8	
				14,434·2	
9.—12. January 1947	35·3	35·33	691·6	$2{,}302{\cdot}7\times10^6$	
	35·2	35·25	3,227·3	10,721·0	Total salt = 21 thousand million tons
	35·1	35·15	1,383·3	4,582·2	
	35·0	35·05	1,007·9	3,329·2	
				20,935·1	
22.—28. January 1947	35·3	35·33	853·1	$2{,}840{\cdot}4\times10^6$	
	35·2	35·25	2,401·5	7,977·7	Total salt = 20 thousand million tons
	35·1	35·15	1,672·3	5,539·6	
	35·0	35·05	1,148·7	3,794·3	
				20,152·0	
11.—14. March 1947	35·4	35·42	320·9	$1{,}071{\cdot}2\times10^6$	
	35·25	35·33	1,548·1	5,274·3	Total salt = 13 thousand million tons
	35·0	35·13	1,961·4	6,493·5	
				12,839·0	

Between the December and the first January surveys, there was a considerable increase in the amount of salt in the region. This indicates that even if evaporation had increased the salinity at all, a large influx of salt water must have occurred. This is in accordance with a suggestion made earlier in the paper. To preserve continuity of volume, some outflow must have taken place into the central part of the North Sea. Since the salinity of the out-flowing water would be less than that of the water entering from the Channel, there would be a net gain of salt in the area as indicated.

There appears to have been little change in salt content of the area in the interval between the January surveys. The slight decrease shown is insignificant in view of the approximations used; it may represent a diffusion of salt across the boundaries, or may be the result of an incomplete knowledge of the salinity distribution.

A considerable change took place in the six or seven weeks between the second survey in January and that made in March. Salinity of part of the central water body had increased by 0·1 $^0/_{00}$ to 35·4 $^0/_{00}$ although the salt content of the Bight as a whole appeared to have dropped by a third of its January figure. It is thought that evaporation may have been responsible for the increased salinity, and that the loss in salt was caused by a diffusion of salt across the 35 $^0/_{00}$ isohaline contrary to our initial assumption. The discontinuities found on the earlier cruises may have broken down to some extent as a result of the cross-Bight easterly winds, and mixing would have occurred between coastal and central water types. Salinity sections across the Southern Bight suggest, in spite of the scantiness of these data, that gradients encountered in March were less steep than those of January. Although the heavy precipitation, and consequent widespread flooding experienced in England throughout March, would hardly have affected the sea conditions by the time of the mid-March survey, run-off from rivers would have been fairly high, as rainfall for the winter was above average. The continued addition of fresh water to the coastal regions would result in a corresponding outflow to the central North Sea, evidence of which has already been found in the T-S diagrams.

Further information can be gained from the results of liberations of drift-bottles made on three of the cruises. From the liberation of two batches on the cruise in early January, 21 out of the 25 bottles recaptured were returned from positions north-east of where they were liberated. Four apparently passed through the discontinuity and were recovered from the Norfolk coast. The suggestion is that as most of the bottles stayed in the central water body, the discontinuity was pronounced. This is supported by the fact that there was no appreciable loss of salt across the 35 $^0/_{00}$ isohaline between this survey and the next. Towards the end of January drift-bottles were again released, and of 21 recovered, 17 went ashore on the Suffolk coast. This indicates that in the days following the survey, i.e., in February, the bottles were driven through the discontinuity, which itself would be breaking down under the influence of the easterly winds. It is not surprising, therefore, that a loss in salt appears to have taken place. The third set of drift-bottles liberated in March moved, without exception, to the north-east under the influence of winds which were mainly from the south-west. Such conditions would favour the re-establishment of the discontinuity system.

Evaporation over the Southern North Sea.

The evaporation of 10 cm. of water from a homogeneous column of depth 36 m. (an average depth for the Southern Bight) would increase

the salinity from 35·00 ‰ to 35·10 ‰, assuming the complete vertical mixing which is usual in winter. Bowden (1950) gives in his Table III the computed values for the mean monthly evaporation over the Irish Sea. Evaporation is highest in December with a figure of 8·7 cm.

Harvey (1925) has given the figures of 100 and 110 cm. as the yearly evaporation for 1922 and 1923 respectively over the English Channel, so that a value of 10 cm. for a winter month deduced from his figures is not unreasonable. Furthermore, Sverdrup (1945) states that "During outbreaks of polar continental air, the daily evaporation may be five times the average winter maximum". As such conditions were undoubtedly prevalent in February 1947, it appears quite possible for the increase in salinity previously mentioned to have been caused by evaporation. We may attempt to calculate evaporation during the period of the easterly winds (21. January—25. February) from the empirical formula.

$$E = k\ (e_w - e_a)\ W,$$

where e_w denotes the water vapour pressure at the sea surface (i.e., saturated vapour pressure at the temperature of the sea surface), e_a the water vapour pressure in the air, and W the mean wind speed. If W is measured in metres per second, e_w and e_a in millibars, E in mm. per day,

Table 2.

Computation of Evaporation over the Period 21. January-25. February 1947.

Air temperature, Gorleston

Five-Day Mean		
January	23	33·5°F.
	28	31·0
February	3	34·0
	8	30·0
	13	29·0
	18	29·0
	23	27·0

Average air temperature 30·5°F.
= —0·8°C.

Sea temperature, "Smith's Knoll"

January	20	6·1°C.
	25	5·7
	30	4·3
February	4	3·6
	9	2·8
	14	2·4
	19	2·3
	24	1·9

Average sea temperature 3·6°C.

Mean sea temperature 3·6°C.
Saturation vapour pressure at this temperature 7·91 mb.

Mean air temperature —0·8°C.
Saturation vapour pressure at this temperature 5·76 mb.

Mean relative humidity 88 % (see Table 3)
Air vapour pressure = 88 % × 5·76 = 5·07 mb.

Mean wind strength, February, 9·4 m. per sec.
Computed evaporation = E = 0·108 $(e_w - e_a)$W
(mm. per day)
= 2·88

Evaporation for the period (35 days) = 100·9 mm.

k can be taken as 0·108. There is not unanimous agreement amongst investigators as to the value of this constant, which seems to depend upon the conditions under which observations are made. The observations of humidity, wind, and sea and air temperature used in the present estimate of evaporation were obtained under similar conditions to those experienced by Bowden, so that his figure of 0·108 is probably applicable in our case. Table 2 gives details of the computation. Air temperatures are those recorded at Gorleston, sea temperatures those at "Smith's Knoll" lightvessel. Any discrepancy which may arise from the measurement of these quantities at separate stations is thought to be small compared with the mean difference and with the other necessary approximations. The mean wind strength is based on the values given in the *Monthly Weather Report* for February, so that this period is not strictly concurrent with the other measurements. The results show that evaporation during the 35-day period was about 10 cm.

The following approximate figures for rainfall over East Anglia have been taken from the monthly rainfall maps of the Meteorological Office (*British Rainfall*, 1947). They are expressed as percentages of the standard period 1881—1915.

January 100—125 %, slightly above average.
February 100—150 %, above average.
March 200—300 %, very wet, especially about mid-month, with flooding later.
April 100—125 %, slightly above average.

It is obvious then that precipitation was considerable, and must be taken into account in any work on evaporation. The rainfall in

Table 3.

Estimate of Precipitation during February 1947.

Station	Rainfall mm.	Mean relative humidity
Spurn Head	51	99
Gorleston	54	82·5
Felixstowe	31	88
Southend	34	—
Manston	34	84
Average value	41 mm.	88 %

"Reduced" rainfall over sea = 41 mm × 0·89 = 36·5 mm. for 28 days of February. Assuming the same daily rainfall, this would amount to 46 mm. for the 35-day period.

Excess of evaporation over rainfall = 101 — 46 mm.
= 55 mm.

Mean relative humidity obtained from all available Meteorological Office data (13 observations) for February and March for the southern North Sea = 89 %.

February at five stations has been averaged and reduced by the factor 0·89 (following B o w d e n) to give an estimate of rainfall over the sea (Table 3). The excess of evaporation over precipitation is thus 5 to 6 cm.

Although as a result of the necessary approximations the different processes affecting salinity cannot be distinguished, it seems clear that several processes are at work, each exerting its own influence on the sequence of events.

Comparison with the Cold Winter of 1928-29.

As far as can be judged from the data available, conditions in 1947 greatly resembled those in 1929. In the latter year, however, more observations were available in the area to the north, where a second body of cold water was found to extend westward into the North Sea from the north Danish coast. Owing to the lack of data it is not possible to say whether a similar phenomenon occurred in 1947.

The cold water found 50 miles off the Friesian Islands in 1947 was about 4°C. colder than the water in a similar position in February 1929 (—1·8°C. compared with +2·5°C.) and slightly colder (by 1°C.) than the tongue of cold water extending from the Danish coast.

The extent of the periods of easterly winds were similar for the two winters, but winds were generally stronger in 1947 and from the north-east quadrant rather than from the south-east as in 1929. It appears therefore that conditions were somewhat more extreme in the 1946—47 winter.

Summary.

The winter of 1946—47 was exceptionally cold, with February the coldest for fifty years.

Salinity observations made on research ship cruises provide evidence that the usual movement of water from the English Channel into the southern North Sea took place in considerable strength during late 1946 and January 1947. Later, however, this movement ceased, and in the central North Sea a westwards movement occurred which resulted in ice and water at negative temperatures being brought into the Dogger Bank region. The temperatures dropped to freezing point (about —1.8°C.) on the surface, and almost certainly to 0°C. on the bottom in part of the area.

The fact that discontinuities in salinity and temperature exist between the coastal and the more oceanic waters in the Southern Bight has made it possible to compare the salt content of the oceanic water of the Bight at the time of each survey. This has led to the desire for further knowledge on evaporation, which process can change the salinity *in situ*. There has been a tendency to attribute changes in salinity in this region to water movements, such as occurred in January 1947, but the changes during February and March are here thought to result from evaporation.

The main features of the cold winter discussed are similar to those of 1928—29 described by Lumby and Atkinson, but the conditions appear to have been rather more severe in 1946—47.

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Some Observations on the Mortality of Fish and the Distribution of Plankton in the Southern North Sea during the Cold Winter, 1946-1947.

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THERE are a number of accounts of the effect of unusually low temperatures on coastal marine fauna, but only the following four deal with the effect of cold winters on marine organisms in the open sea: Dannevig (1930a) gave an account of the effect of the low temperatures of 1923—24 on the spawning and distribution of fish along the Norwegian coast between Trysfjord and Langesund on the Skagerak. After the 1928—29 cold winter Johansen (1929) and Dannevig (1930b) described its effect on fish and other marine organisms round Denmark and southern Norway, while Lumby and Atkinson (1929) described the conditions and effect on fish in the southern North Sea.

Late in February 1947, reports began to reach the Lowestoft laboratory of ice at sea and, in early March, of dead fish being caught by trawlers. As it was clear that the very cold conditions were developing in a manner similar to those of 1929, a letter was sent to fishermen in Lowestoft, Yarmouth, and Grimsby outlining the experience of 1929 and asking them to send reports to the port fisheries offices of dead fish and of other unusual occurrences. Jars containing formalin were also sent to trawlers for the preservation of dead organisms other than fish which had been caught. This request for information met with a ready response, and I wish to thank all those skippers and mates, and officers at the ports who provided information, without which this account would have been impossible. The reports may be inspected at Lowestoft.

The cold period occurred during a series of plankton surveys in January, February, and early March in the southern North Sea, which were part of a programme of investigations into the quantitative

distribution of the eggs and larvae of plaice and other fish. Although the full programme could not be completed owing to the persistent easterly gales, there was a nearly complete survey (24.—28. January) of the Southern Bight immediately prior to the cold weather and one immediately following it (11.—14. March), with two somewhat reduced surveys during the cold weather (15.—18. February and 27. February—1. March). On these surveys vertical hauls with the Hensen net were carried out at each station and observations were made of surface water temperature and salinity, with occasional sub-surface observations. During the survey of 15.—18. February, the pattern of stations was altered to cover the area found to be seriously affected by the cold conditions. The results of these plankton surveys by the "Sir Lancelot" and the reports from fishermen form the biological material of this paper.

The hydrographical conditions.

A full account of the hydrographical changes that occurred during this period is given by V a u x (1953). However, in order to provide an immediate background to the biological observations described in this account, a brief résumé of the sequence of events, with special reference to the temperature changes, is given here.

Towards the end of January 1947, the intensification of a high pressure system over Scandinavia gave rise to strong easterly winds over the North Sea. Over the southern North Sea these strong winds started on 21. January and persisted with little abatement until 23. February (comparable dates in 1929 were 21. January to the end of February). Between 23. February and 15. March, the wind varied greatly in direction and force but the air temperature remained largely below 0°C. After 15. March the air temperatures rose considerably.

The continuous cold easterly gales caused rapid cooling of the surface water over a very wide area. Ice formed extensively along the continental coast from about the Scheldt to the Skagerak, and also in a number of isolated shallow areas along the east coast of the British Isles. Off the north-western Dutch coast cold water and ice that had been formed among the Friesian Islands were carried out to sea to form a tongue of pancake and brash ice. The "Sir Lancelot" steamed through the edge of this tongue some 35 miles north-west of Vlieland on 17. February, and ice extended as far as the eye could see. Some of the ice was discoloured brown, presumably from sand which had been picked up in the inter-tidal zone where it had been formed. Between the ice the sea water was full of ice crystals that gave the water an oily appearance. At this time the surface water 0°C. isotherm in this tongue reached about 70 miles from the Dutch coast (Figure 1; see also V a u x, Figure 9).

Although the easterly gales ceased before the end of February, the air temperature over the southern North Sea remained lower than that of the sea water for a further one to three weeks, with the result that in most areas the sea water continued to become colder. At the "Pit"

lightvessel on the northern edge of the cold tongue the minimum surface-water temperature of —0·9°C. was reached on 1. March, while at the "Smith's Knoll" lightvessel, the minimum temperature of +1·3°C. was not reached until 12.—16. March.

In the centre of the Southern Bight, the minimum temperature was approximately 3·0°C. in mid-March.

Sub-surface temperature and salinity observations were taken at a small number of stations, including the region of the cold tongue of

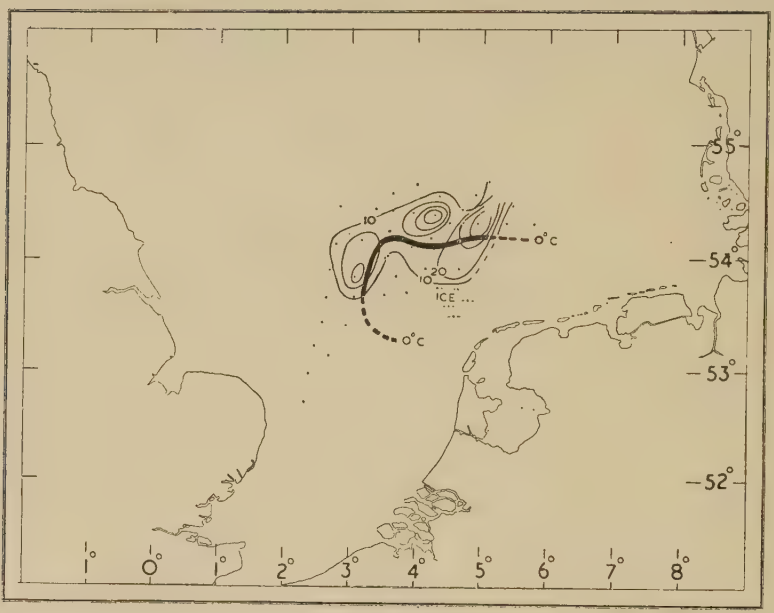

Figure 1. Distribution of young (stages 1—6) plaice eggs. Contours at 10, 20, 40, 80 eggs below 1 sq. m. Surveys of 15.—18. February and 27. February —1. March combined. 0°C. surface isotherm shown by a heavy line.

water. These showed that in this latter area the cold, less saline water from the continental coastal area overlay somewhat warmer, more saline water, although elsewhere the water column was virtually homogeneous.

In the area of the cold tongue the bottom temperature did not reach its minimum until mixing of the water column was once more complete; this occurred about mid-March. V a u x considers that, at this time, the 0° bottom isotherm extended to about the position of the —1° surface isotherm found during the February surveys, that is, it reached a maximum distance of some 60 miles from the coast.

Thus minimum bottom temperatures occurred throughout the area at about mid-March.

The distribution of surface-water temperature in the southern North Sea at four dates between 29. January and 15. March is shown by V a u x (Figs. 7, 9, 11, and 12).

From mid-March water temperatures steadily increased all over the area, and the summer of 1947 was an unusually warm one.

Relation between the cold water and the spawning of plaice, cod, and dab.

The analysis of fish eggs and larvae caught during the survey of 15.—18. February in the area of the tongue of cold water showed that cod, plaice, and dab eggs were abundant in the area covered. Figures 1, 2, and 3 show the distribution of plaice, cod, and dab eggs expressed

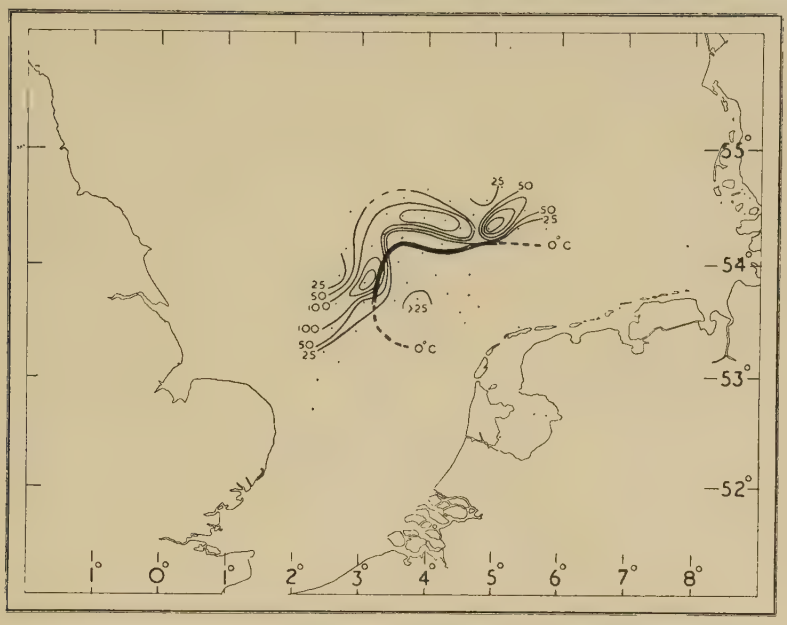

Figure 2. Distribution of cod eggs. Contours at 25, 50, 100, 200, 400 eggs below 1 sq. m. 0°C. surface isotherm shown by a heavy line.

as the number of eggs below one square metre of surface. As the incubation period of plaice eggs covers many days at low temperatures and old eggs may have drifted considerable distances, only the very young eggs are included (A p s t e i n' s stages 1—6), while for the cod and dab, all eggs are shown. However, in all three species most of the eggs were early stages, indicating that little or no spawning had begun in the area before the cold weather started and that the eggs were probably caught at a position not far from the area in which they had been spawned.

Owing to the paucity of bottom temperature observations it is not possible to relate the observed egg or fish distributions to the actual temperatures that the fish had been experiencing on or near the bottom. However, mixing would have cooled the bottom water to a certain extent in this area, and though it is improbable that the offshore bottom

water north-west of Texel Island would by this time have fallen below 0°C., it seems clear that there would have been a north-westerly extension of the bottom isotherms between 0°C. and +2°C. in approximately the same geographical position as the 0°C. surface isotherm.

It is seen that in all three species but particularly the cod, the eggs lay chiefly round the northern and western edge of the tongue of cold water, the position of which is indicated in the diagrams by the 0°C. surface isotherm. The usual spawning behaviour of the plaice is that

Figure 3. Distribution of dab eggs. Contours at 10, 20, 40, 80, 160 eggs below 1 sq. m. 0°C. surface isotherm shown by a heavy line.

mature fish come to the Southern Bight and Borkum area, where they spawn in January and February, a few plaice spawning in the intermediate area about 60 miles west of the island of Texel. Similarly some cod come south to spawn in the Southern Bight and Helgoland Bight (Aurich 1941; Simpson 1949, 1950) in January, February, and March.

The large number of plaice eggs on about 54°20'N. and between 4°E. and 5°E. is in a position 40—50 miles W.N.W. of the centre of the Borkum plaice spawning area located by Aurich (1941), and it would seem most probable that some, if not the majority, of these eggs were laid by plaice which had been forced west-north-westwards away from their normal spawning area by the cold conditions. This

happening would be similar to that described by D a n n e v i g (1930a), in which cod were forced from their normal coastal area in the Skagerak during the severe winter of 1924. The extension of the area of plaice eggs west and south round the tongue of cold water, and to a greater extent the distribution of cod eggs round the western edge of the cold water, suggest that some plaice and cod may have been diverted westward during their southward migration and spawned along the edge of the cold water before reaching the more southern grounds. This

Figure 4. Distribution of plaice eggs about to hatch (stages 20 to hatching). Contours at 5, 10, 20, 40 eggs below 1 sq. m. 11.—14, March.

possibility is supported by the evidence of the distribution of dead fish described below. That there was an actual accumulation of plaice and cod in the areas where their eggs were found is supported by the unusually large catches of these species that were made by commercial trawlers in these positions, but this will be discussed further at a later stage as there are other possible causes of such increased catches.

As far as the dabs are concerned little is known of their spawning migration but the distribution of eggs in 1947 (Figure 3) was different from that found in 1948 (S i m p s o n, 1950) when the temperatures were normal. In 1948, dab eggs were to be found in late February and March in considerable numbers all over the area occupied by the tongue of cold water in 1947, with the highest densities occurring towards the

Dutch coast. This suggests that the spawning dabs were also forced westwards from their normal spawning area.

In normal years the plaice has virtually finished spawning south of 53°N. by the end of the first week of March, but the survey of 11.—14. March showed the presence of considerable numbers of young plaice eggs in this area, eggs that, calculated from Apstein's tables, had been laid within the previous four to five days. These observations would confirm those of Dannevig (1930a) that cold conditions postpone or delay spawning. It does not appear from the numbers of older eggs found in February and March 1947 (see Figure 4) that the cold conditions in the Southern Bight caused a significant reduction in the total number of eggs laid there. There was certainly nothing comparable with the almost complete prevention of spawning that was observed by Smith (1948) of the plaice kept at Port Erin hatchery, where the water temperature in the plaice pond fell to 0°C. for two weeks and reached —1·1°C.

There are, however, no data to show what effect the cold conditions nearer to Helgoland had on the spawning of other fish which normally spawn in February in that area, as opposed to the Southern Bight. It would seem most probable that at least the position and time of spawning of the whiting, dab, flounder, and sprat will have been affected.

There is little information on whether the cold conditions seriously affected the survival of the 1947 brood of plaice. The severe conditions in the Helgoland Bight where the spawning of the plaice normally reaches its peak in February may be expected to have affected the survival of the plaice which normally grow up in this area. Not only was the spawning probably displaced westwards, but the hatching of the eggs will have been delayed, the pelagic stage of the larvae will have been prolonged, and the eggs and larvae may have been drifted westward. With regard to the Southern Bight spawning, it seems unlikely that this will have been so greatly affected, as the spawning had reached its peak when the cold weather started, the temperatures south of 53°N. did not fall so low, and there seems to have been little westerly movement of the mass of Southern Bight water. In fact the distributions of plaice eggs about to hatch (Figure 4) and larvae (Figure 5) on the survey of 11.—14. March show no westerly displacement, but rather an easterly displacement. Such an easterly movement of the water in the Southern Bight — in the opposite direction to the easterly wind — could be explained if the westerly drift in the central North Sea, due to the easterly gales, caused the water in the narrower and thus more sheltered Southern Bight to be drawn towards the Texel area. If this did occur it will have brought the eggs and larvae in the Southern Bight towards the Dutch coast, which might have been an advantage to the larvae. Preliminary unpublished data kindly made available to me by Mr. Boerema, of the Hague, suggest that the 1947 year-class was not greatly different in strength along the Dutch coast from the 1946 or the 1948 year-classes.

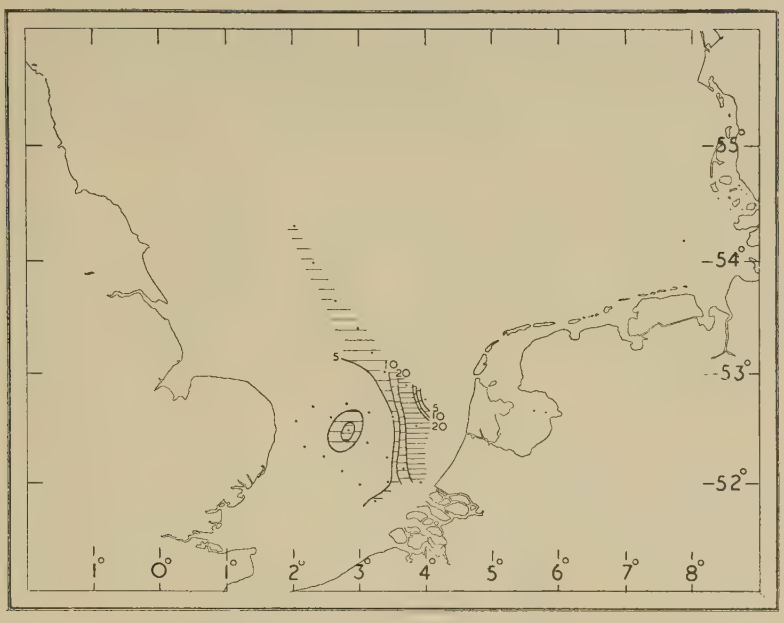

Figure 5. Distribution of planktonic plaice larvae and post-larvae. Contours at 5, 10, 20 below 1 sq. m. 11.—14. March.

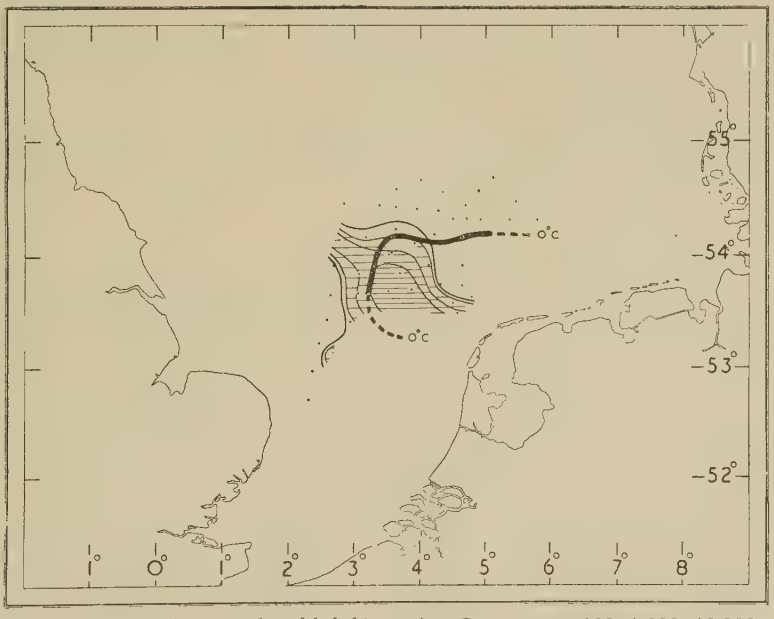

Figure 6. Distribution of *Biddulphia aurita*. Contours at 100, 1,000, 10,000, and 100,000 cells per m.^{3} Surveys of 15.—18. February and 27. February —1. March combined. 0°C. surface isotherm shown by a heavy line.

Preliminary figures for the relative strengths of plaice year-classes as determined from catches of English North Sea trawlers also show that the 1947 year-class did not differ much in strength from the 1945 and 1946 year-classes. Thus it does not appear that in 1947 there was a major change in the survival of plaice eggs or larvae in this area.

Planktonic organisms.

An examination of the distribution of the phyto- and zoo-plankton organisms caught on the February and March surveys showed one very striking result of the easterly gales. It was found that on the 15.—18. February survey, the typically neritic diatom *Biddulphia aurita* had been caught over a wide area closely related to the tongue of cold water (Figure 6).

The *Biddulphia aurita* occurred in chains of up to 90 cells, which were apparently growing rapidly when caught. O s t e n f e l d (1913) describes this species as a neritic eurythermic species, but which, in its planktonic form, becomes stenothermic, with a low optimum. O s t e n f e l d records that, although typically neritic, under suitable conditions it can produce a rich flowering in the plankton in February. L u c a s (1940) has shown that *B. aurita* is to be found more commonly in the plankton of the southern North Sea than is suggested by O s t e n f e l d. But its occurrence has been erratic and short-lived, though it has reached considerable densities for short periods in February or March in some years.

It is not possible to tell whether the observed distribution of *Biddulphia aurita* was due to cells being carried from the coast or due to the rapid multiplication of cells in offshore water which was of the optimum temperature and salinity, combined with the brilliant sunshine which accompanied the easterly gales in this area. It would seem likely that a combination of the two processes may well have been responsible in 1947, though the occurrences reported by L u c a s when temperatures were not exceptional would suggest that strong winds carrying coastal water into more offshore areas is likely to have been the more important factor.

It may be noted that in the area of the ice the use of plankton nets was made difficult by the large amount of ice crystals in suspension in the water, apart from the freezing of ropes and blocks. The zoo-plankton organisms, when examined immediately after being brought on board were not at all active; in fact they appeared paralyzed, for after the sample had lain in the laboratory aboard the ship for a few minutes the copepods and other organisms became extremely active.

Of the other plankton organisms in the area the catches on the 11.—14. March survey showed few features worthy of special comment. Compared with the survey of 24.—28. January there was, as is normal for this period, a great development of diatoms and small copepods. *Phaeocystis,* Medusae, and Ctenophores, which normally increase during February and March, were, however, still present only in smaller numbers, while *Oikopleura* sp. was considerably reduced in numbers.

The occurrence of dead fish.

The importance of the chief trawl-caught fish from the southern part of the North Sea is shown by the Lowestoft landings for February and March 1947:—

1947	Plaice	Skates and Rays	Cod	Soles	Whiting	Dabs
	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
February	13,935	4,515	3,934	2,822	2,007	682
March	16,635	2,118	16,599	4,846	3,618	2,604

The relation of the number of landings of fish of these categories to the number of ships reporting fish caught dead in the trawl is shown in Table 1.

Table 1.

Total number of landings by 1st class vessels at Lowestoft of the commoner species of fish for February, March, and April 1947, and the numbers of reports of fish dead in the trawl at (A) Lowestoft and (B) Lowestoft, Grimsby, and Great Yarmouth.

	Soles	Cod	Whiting	Dabs	Plaice	Skates and Rays
February						
Total Landings	149	173	148	154	173	150
Reports of Dead Fish (A)	—	—	—	—	—	—
Reports of Dead Fish (B)	—	—	—	—	—	—
March						
Total Landings	203	225	212	223	228	143
Reports of Dead Fish (A)	28	21	16	5	4	1
Reports of Dead Fish (B)	45	32	24	6	4	1
April						
Total Landings	153	196	176	193	201	56
Reports of Dead Fish (A)	4	3	—	—	2	1
Reports of Dead Fish (B)	4	3	—	—	2	—

From the considerable number of reports received from fishermen, a fairly complete picture of the incidence of dead fish west of about 4°30′E. can be obtained, though even here care has to be taken in relating the frequency of reports in different areas to the distribution of fishing.

The distribution of fishing by British trawlers is given in Figure 7, and this shows that in March, in the area under discussion, the fishing was concentrated along the northern edge of the cold tongue of water (rectangles G7, H7, J7) and in the very cold water north-west of Vlieland (rectangles J5 and J6), but that there was little fishing just south-west of the cold tongue (rectangles G5 and H5), although there

was more fishing again in the central part of the Southern Bight (rectangles G3, G4, and H4). In April the distribution of fishing was rather different with most fishing west (rectangles G7 and G6) and south-west of the cold tongue (rectangles H4, H5, and H6).

The main point to be noted from this distribution of fishing is that there are very few observations from rectangles G5 and H5. If there had been as many observations there as north and south of these rectangles, it seems likely that the distribution of dead fish reports would not have been separated into two apparently distinct areas but would form one more or less continuous area.

The fishing in J9 in March and April yielded no reports of dead fish and the fishing well to the east in L8 and L9 carried out late in April also yielded no such reports.

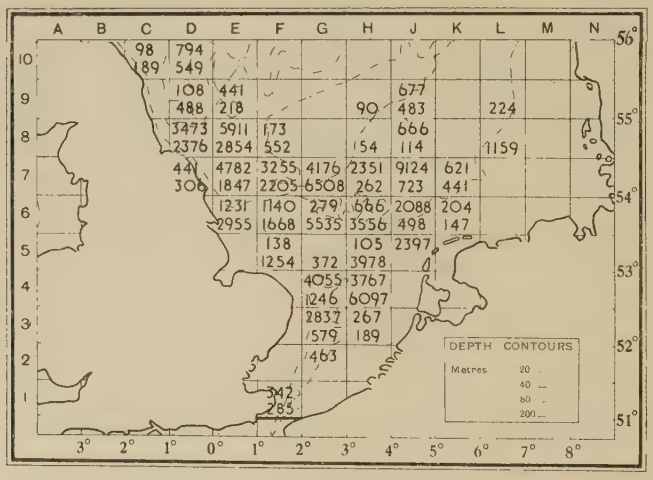

Figure 7. Number of hours fishing by statistical rectangles in March (upper figures) and April (lower figures) 1947.

The statistical returns of the fishing fleet have been used later in this report for determining the distribution of soles, plaice, and cod in the neighbourhood of the cold tongue. Although they have given fairly conclusive evidence of altered distributions due to the cold conditions, care must be taken in their interpretation as three other factors may also have influenced the catches of fish in this area in 1947. Firstly, the cold winter occurred so soon after the partial closure of the North Sea by minefields that the stocks of fish were in a state of rapid change due to heavy fishing and their distribution as well as abundance is likely to be anomalous, apart from the effect of the cold winter. Secondly, the fishing grounds east of 4°E. had been declared free from mines in the latter half of 1946, with the result that these protected grounds might be expected to have a greater density of fish than if they had been fished as intensively as the grounds west of 4°E. Thirdly,

the behaviour of fish at these low temperatures may have differed from that at normal higher temperatures, and may therefore have altered the ease with which they were caught.

Dead fish were first caught in the last days of February, while the majority were caught in March. After mid-April there were no further occurrences. The March record from Lowestoft shows that the ships reporting dead fish per hundred landings varied between species in accordance with the following list:—

Soles	Cod	Whiting	Dabs	Plaice	Skates and Rays
13·4	9·1	7·1	2·2	1·7	0·6

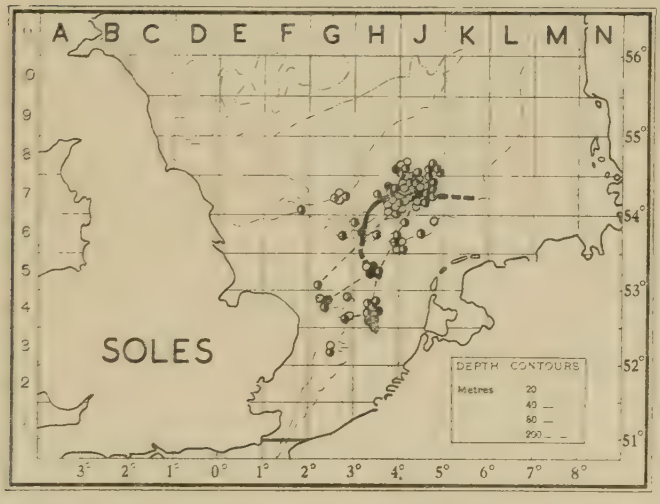

Figure 8. Showing the positions from which dead fish were reported by British trawlers.
Reports received 1.—20. March = open circles; 21. March—5. April = halved circles; after 5. April = closed circles.

Although it is not possible to give any precise figure of the mortality due to cold expressed in proportionate numbers of live and dead fish, a consideration of the foregoing and of fishermen's reports leads to the conclusion that, as in 1929, the sole was the chief sufferer while plaice and "skates and rays" appear to have escaped lightly. The positions of reports of dead fish are shown in Figures 8—12.

Soles. (Figure 8)

The first reports of dead soles were from trawlers landing during the first week in March and it would appear that dead fish (soles, whiting, cod, and dabs) were first recognized at sea on about 1. March from an area some 60 to 65 miles N.W. to N.N.W. of Terschelling

Island. At this time also dead soles were reported from the deep water (30—38 fathoms) of the Silver Pits just south of the Dogger.

By the end of the first week of March dead soles were reported from a wide area extending from a little north of the "Pit" lightvessel south to the deeper water south-east of Lowestoft and westwards to about 2°30'E. (The positions of lightvessels and buoys referred to are shown in Figure 15 on p. 171.)

The increase in proportions of soles that were dead in the Silver Pits area was well shown by the reports of Skipper C o d d of the trawler "Thracian". Working from his experience of increased catches of soles in this area during the 1929 cold winter, he fished regularly there during February, March, and April 1947. Between 10. and 20. February he caught an average of 10 stones of soles per haul (probably 3 hours duration), all in good condition. Between 24. February and 4. March he averaged 20 stones of soles per haul, of which 10 % were dead. Between 8. and 15. March the catch remained at 20 stones per haul, but there were now 20 % dead. Between 17. and 24. March 50 % of the soles were dead, while fishing between 29. March and 7. April yielded 100 % dead soles in the deep water area. He then steamed 5 miles north to a position where he fished on sand in 21 fathoms and caught soles, cod, and plaice, all in perfect condition. On the next trip starting 9. April, he fished in the deep water of the western end of the Silver Pits in 30 to 42 fathoms and the soles he caught were all alive.

During the second half of March the reports showed the highest proportion of dead soles, many fishermen reporting at least 50 % and many 100 % dead, from the whole of the area of the cold tongue (rectangles J7, H7, and H6). The few ships that were fishing between the S.T. buoys and the Brown Ridges also reported a large proportion of dead soles. Many of the dead soles had yellow or white patches about 2 cm. across on the skin, while the skin became quite loose and easily removed on others. At the end of March many skippers reported large quantities of decaying fish and the water becoming polluted. Other skippers working further south towards the Brown Ridges reported unusually frequent occurrences of soles swimming near the surface during the day and night.

Reports of dead soles and other fish fell away steadily in April. Although this was partly due to ships moving to other grounds, fewer dead fish were trawled up after the second week in April and it does appear that mortalities had ceased some little while before and that the remains of dead fish were largely demolished by scavenging animals by mid-April.

Figures 13A—F show the catch of soles per 100 hours fishing by 1st class steam trawlers in February and March in 1946 and 1947, and the mean for 1932—38. These charts show the increased density of soles in the south-western part of the North Sea that occurred after the war. However, a comparison of the 1946 and 1947 charts shows that in 1947 there were low densities of soles in the rectangles covered by the tongue of cold water — H5, H6, H7, J5, J6, and J7 — but relatively

high catches to the west and south of the cold water. This, combined with the observations from the "Thracian", suggests that, as in 1929 (Lumby and Atkinson, 1929), the soles moved westward away from the cold water and were to be found in unusually large numbers in the deeper water to the south and west.

Figure 14 shows the landings of soles per 100 hours fishing by 1st class steam trawlers in these western and southern areas during 1946, 1947, and 1948 (rectangles E6—7, F5—7, G3—7, H3—4) and it is seen that during February to May 1947 inclusive, the landings from these areas were far higher than would have been expected under normal conditions. In March and April they even exceeded the 1946 landings for these months. These figures do not include the large numbers of soles that were dead and were rejected at sea. On the other hand, an examination of the landings per 100 hours fishing in February to April in the area of the cold tongue (rectangles H5, H6, and H7) shows catches that were not inflated. Table 2 gives the catches in cwt. per hundred hours fishing in the three rectangles, by months.

Table 2.

	Jan.	Feb.	March	April	May	June
1946	39	44	12	15	4	7
1947	36	3	5	6	6	3
1948	5	3	1	1	0·3	2
	July	August	Sept.	Oct.	Nov.	Dec.
1946	7	7	10	16	16	33
1947	5	4	5	5	3	6
1948	0·5	3	2	2	2	3

The total catch of 7,700,000 kg. of soles from the North Sea by all countries in 1947, and 4,720,000 kg. in 1948, compared with 5,164,000 kg. in 1938, suggests that even though this measure is rough, the mortality to the stock as a whole due to the cold conditions was not catastrophic.

It is interesting to note that the year-class resulting from the spawning of the sole immediately following the cold winter was exceptionally abundant (Margetts, 1950). Bückmann (1934) has estimated the strength of sole year-classes between 1921 and 1932 and has found that following the two cold winters, 1924 and 1929, the 1924 year-class was abundant while the 1929 year-class, though above average, was not outstanding. It is perhaps conceivable that cold winters may cause conditions favourable for the survival of sole fry in the following summer.

Cod and Whiting. (Figures 9 and 10)

The reports of dead cod and whiting are probably not so complete as are those for soles, as the former species realize a lower price and therefore were less important to the fishermen. Two reports stated that the dead codling and whiting caught were considered to be good fish

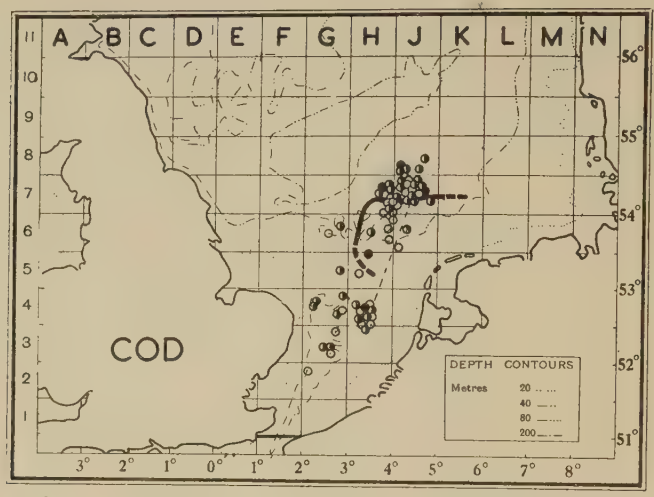

Figure 9. Showing the positions from which dead fish were reported by British trawlers.
Reports received 1.—20. March = open circles; 21. March—5. April = halved circles; after 5. April = closed circles.

that had been dumped by other trawlers; while this is possible in a few cases, it is unlikely that it applied to the very large number of dead cod and whiting that were reported. Many of the dead cod caught towards the Brown Ridges were large mature fish that would not have been rejected.

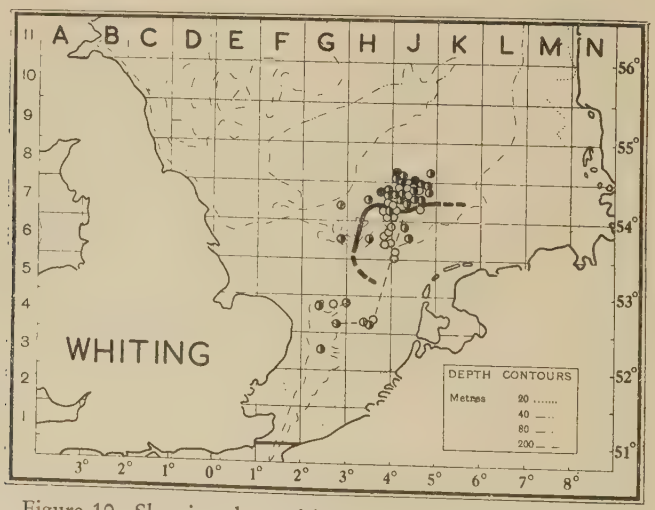

Figure 10. Showing the positions from which dead fish were reported by British trawlers.
Reports received 1.—20. March = open circles; 21. March—5. April = halved circles; after 5. April = closed circles.

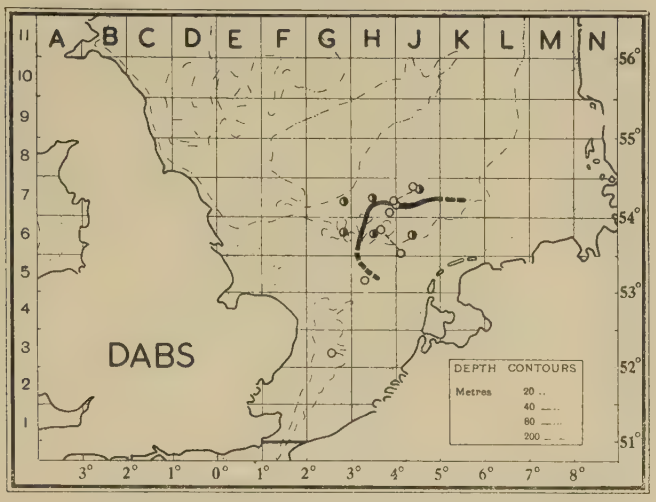

Figure 11. Showing the positions from which dead fish were reported by British trawlers.
Reports received 1.—20. March = open circles; 21. March—5. April = halved circles; after 5. April = closed circles.

Dead cod and whiting were first reported by trawlers fishing in the vicinity of the "Pit" lightvessel and landing their fish on 7. March. The incidence of dead cod and whiting increased during March until about 18. March when all trawlers fishing in the vicinity of the cold tongue (rectangles H5, H6, H7, J5, J6, and J7) were catching them

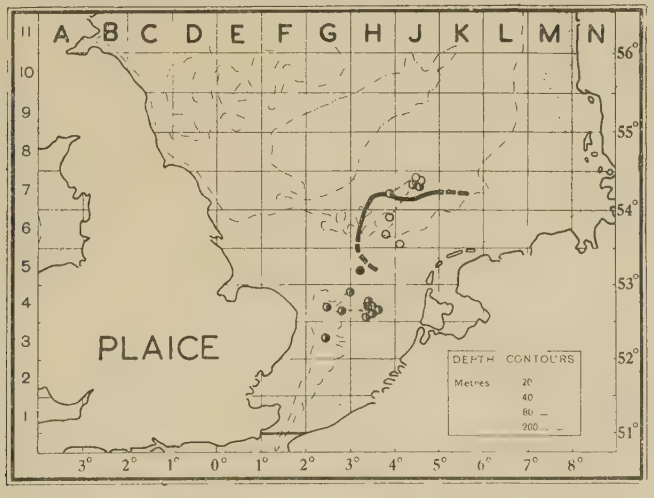

Figure 12. Showing the positions from which dead fish were reported by British trawlers.
Reports received 1.—20. March = open circles; 21. March—5. April = halved circles; after 5. April = closed circles.

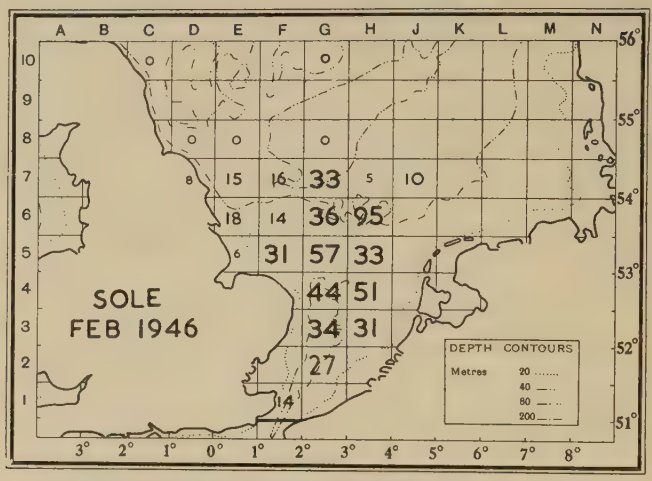

Figure 13 A. Catch of soles by 1st class steam trawlers in cwt. per hundred hours fishing, by statistical rectangles.

in nearly every haul. This state of affairs extended to the Brown Ridges. The majority of dead fish other than soles caught on or south of the Brown Ridges as far as the Gabbards (52°N., 2°10′E.) were large cod. Several fishermen reported that on trips ending 20. March they had been catching 3 or 4 dead large cod every haul about 30 miles south-east of Lowestoft. These were presumably fish that were about to spawn in the Southern Bight in February and March and had been

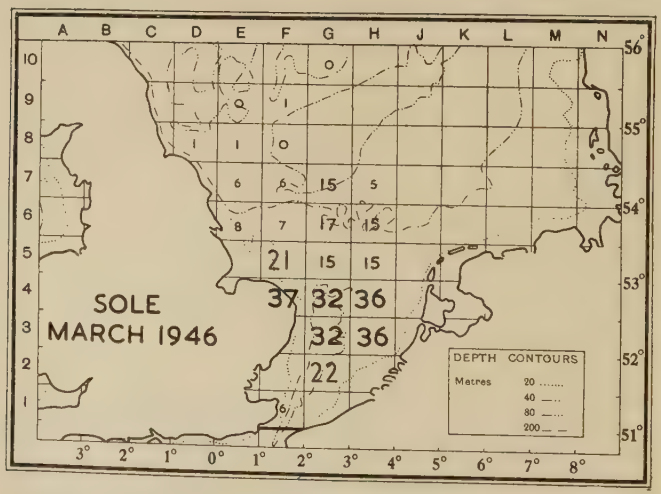

Figure 13 B. Catch of soles by 1st class steam trawlers in cwt. per hundred hours fishing, by statistical rectangles.

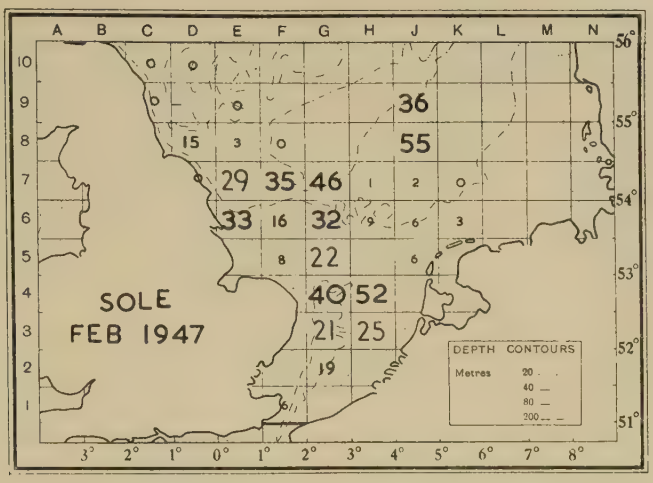

Figure 13 C. Catch of soles by 1st class steam trawlers in cwt. per hundred hours fishing, by statistical rectangles.

severely injured by the cold during their migration southwards from the central North Sea.

During early March many ships made large catches of cod along the edge of the cold water and it appeared that cod were massed there and were moving westward as the cold water extended further west. The catch of cod per 100 hours fishing in each of seven statistical rectangles off Terschelling reached 130 cwt. per 100 hours fishing and

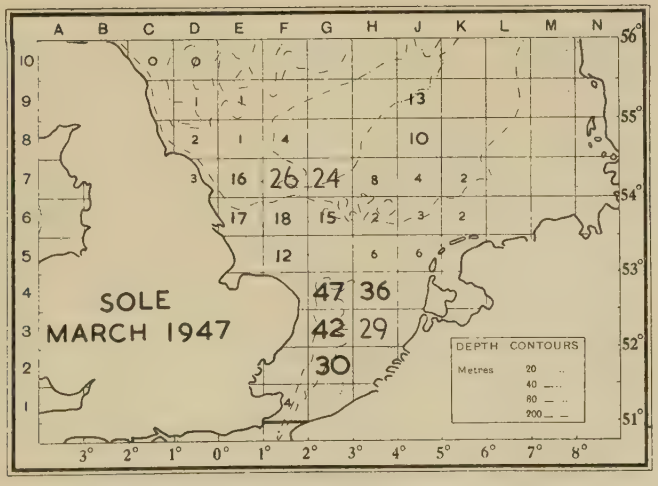

Figure 13 D. Catch of soles by 1st class steam trawlers in cwt. per hundred hours fishing, by statistical rectangles.

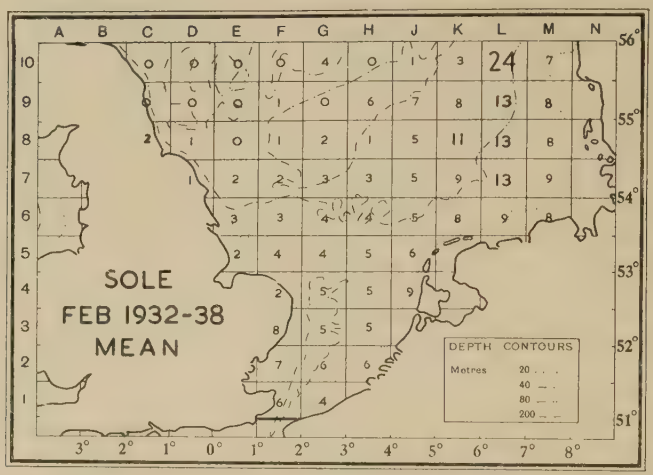

Figure 13 E. Mean catch of soles by 1st class steam trawlers in cwt. per hundred hours fishing, by statistical rectangles.

exceeded 200 cwt. in two of these. In the same area from January to March 1946, January and February 1947, and January to March 1948, the equivalent figures only reached 130 cwt. on one occasion.

The presence of large numbers of cod eggs in this area, already described, would suggest that there was an accumulation of mature spawning cod which had either been pushed westward by the cold conditions or which had been partially held up by the cold tongue

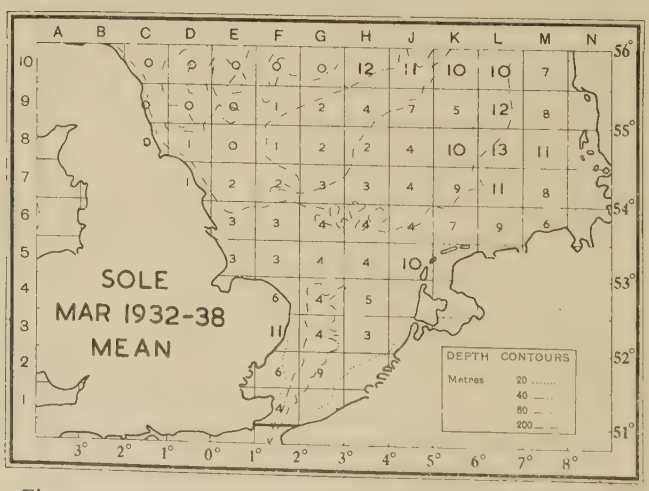

Figure 13 F. Mean catch of soles by 1st class steam trawlers in cwt. per hundred hours fishing, by statistical rectangles.

during the normal movement to their more southern spawning grounds. However, the reports of dead cod off Terschelling usually referred to dead codling, which composed the majority of the catches and therefore would have been smaller immature fish.

The gut contents of the cod were remarked on by several skippers. It was found that the cod stomachs at different times were packed with small fish, particularly dabs and soles, and on one occasion with millers' thumbs (*Cottus scorpius*). It is uncertain whether the small soles here were the true sole (*Solea vulgaris*) or the solenette (*Solea lutea*), which is very abundant along the continental coast.

Dabs. (Figure 11)

The reports of dead dabs started during the first week in March and continued intermittently. Whenever dabs were reported, they had been found in considerable numbers and it appears probable that the lack of reports of dead dabs towards the end of the period was more the result of failing to mention this species (which is of little importance to the English market) than because no dead dabs were being caught. It is also possible that the fact that dabs normally die more rapidly in the trawl than cod, whiting, or plaice would make it difficult to distinguish those dabs that were already dead before being caught.

The distribution of reports of dead dabs as seen in Figure 11 almost certainly makes an incomplete picture and an understatement of the degree to which the dabs were affected by the cold. However, it is difficult to interpret the one report in which dabs were mentioned as dead in the Brown Ridges area as it is in surprising contrast to the lack of supporting reports; it stated "Enormous quantities of extremely small dead dabs with every haul. E. by S. 35 miles from Lowestoft".

Plaice. (Figure 12)

The reports of dead plaice began a little later than for the species already discussed. The first report was from a ship which landed on 11. March and which had been fishing among the ice off Terschelling on about 5. March. A feature of the reports in general was that dead plaice were never found in large numbers. Reports typically used the phrases "dead plaice were only occasional", or "also a few dead plaice". Most reports came from the area of the cold tongue but it is clear that dead plaice must also have occurred southward to the Brown Ridges.

The slightly increased catches of living plaice that occurred round the northern edge of the cold water were not enough to show clearly in the statistics and it would appear that the mortality of plaice cannot have been increased much by this fishing. Estimates of the abundance of each age-group of plaice for the years 1946 and 1947 from market samples show a great reduction in the numbers of the older year-classes in 1947 compared with 1946; this at first might be put down to the effect of the cold winter. However, a careful examination of monthly figures suggests that the great reduction in the stock of plaice which took place in these years occurred particularly during the latter half

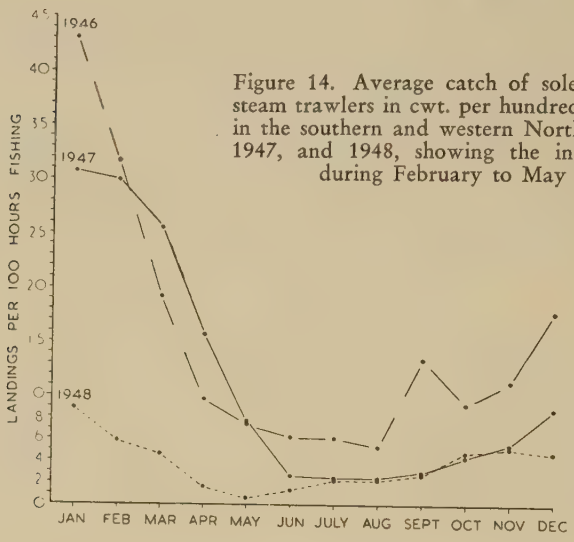

Figure 14. Average catch of soles by 1st class steam trawlers in cwt. per hundred hours fishing in the southern and western North Sea in 1946, 1947, and 1948, showing the inflated catches during February to May 1947.

of 1946, when the area open to fishing was rapidly expanding due to the clearing of minefields (Margetts and Holt, 1948).

Other species of fish.

Apart from the above species there were several reports of individual turbot and brill being found dead during March and single reports referred to dead thornback rays, flounders, conger eels, and sand eels. Of these only the thornback rays are caught in any numbers in the area; it therefore seems likely that this species was not seriously affected.

Porpoises.

Two foetal porpoises were brought into the laboratory at Lowestoft during the cold period. The first had been taken in the trawl of the S.T. "Hosanna" 45 miles east by north of Lowestoft on 1. March 1947, and the second by the S.T. "S. D. J." some 50 miles east by north of Lowestoft on about 27. March. Presumably premature birth had occurred as a result of the adverse conditions. Both specimens were sent to the British Museum of Natural History.

Invertebrates.

The following animals living on the sea-bed and brought up dead in the trawls of three Lowestoft vessels were identified at the Lowestoft laboratory by Mr. I. D. Richardson.

S.T. "Season's Gift" 3.4.47. 2 miles S. of S. T. 3 Buoy.
Phascolosoma vulgare (Blainville)
Aricia cuvieri Audouin and Edwards
Metridium senile (L.)

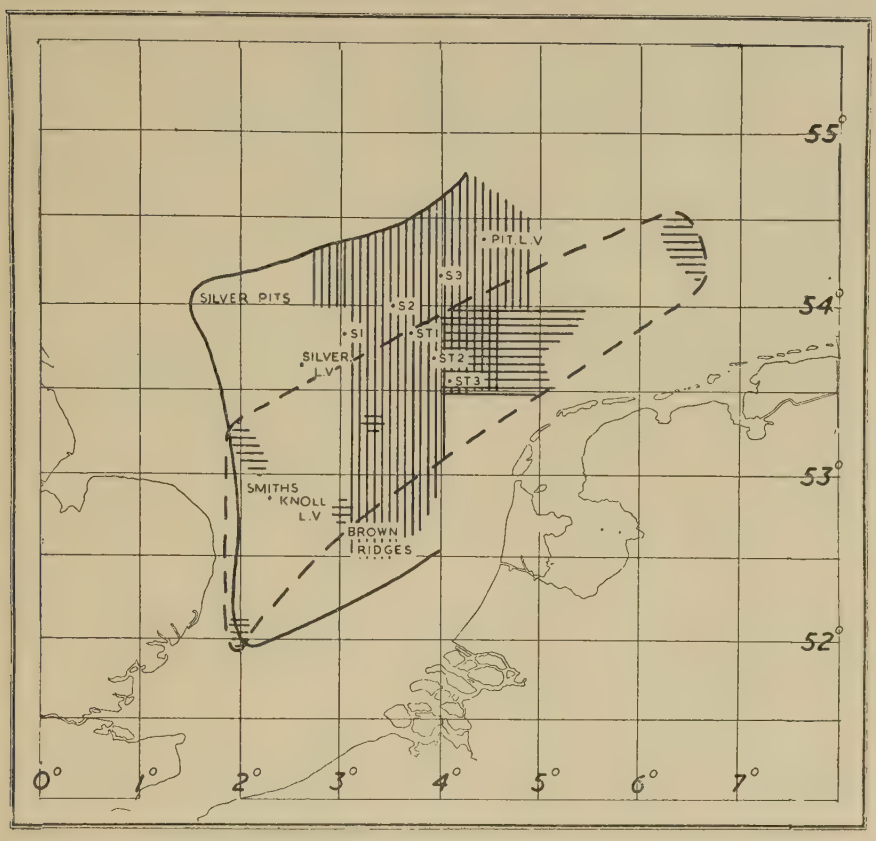

Figure 15. Distribution of reports of dead fish in 1929 (broken line and horizontal shading) from Lumby and Atkinson (1929), and in 1947 (continuous line and vertical shading).

Eupagurus bernhardus (L.)
Nephthys incisa (Malmgren)
Sipunculus sp.
Fragments of polychaetes.

S.T. "Mary Bruce" 29.3.47. 12 miles N.N.E. of "Pit" lightvessel.
Cardium edule L.
Aphrodite aculeata L.

S.T. "Delhi" 18.3.47. S. 2 Buoy (53°32′N.,3°17′E.).
Nereis longissima Johnston
Glycera gigantea Quatrefages
Sipunculus sp.

In addition, crabs (unspecified) and "prawns" among crustacea, and *Ensis* and *Cardium* of the mollusca were found dead in the area between the "Pit" lightvessel and S. T. 2 Buoy; and one report (11.4.47) from the Botney Gut area (53°50′N., 3°E.) stated that all Norway lobsters (*Nephrops norvegicus*) caught were dead.

Discussion.

Comparing the distribution of the dead fish in 1929 and 1947 (Figure 15), it is clear that the dead fish were found over a considerably wider area in 1947 than 1929. Similarly, the abundance of dead fish was considerably greater, though this is partly due to the inflated post-war densities. L u m b y and A t k i n s o n refer to a report that some 750 kg. (15 cwt.) dead soles had been thrown overboard on one trip and on other trips some 40 kg. (0·79 cwt.) dead fish per haul were being discarded as unfit for food.

In 1947, one report referred to 36 baskets (about 25 cwt. or 1,250 kg.) of mixed fish being unfit for food out of one haul of 50 baskets (about 40 cwt. or 2,000 kg.) from the area of the "Pit" lightvessel on about 15. March. Another ship working near the S. 3 Buoy on about 23. March was catching some 0·6 cwt. (30 kg.) dead soles per haul while two others fishing nearby recorded averaging 1·5 cwt. (75 kg.) dead soles per haul. The report with the highest figure for dead soles was that from the S.T. "Thracian" already referred to, in which a haul of $2^1/_2$ cwt. (125 kg.) dead soles was reported from the eastern end of the Silver Pits.

The records of dead fish described in this paper and the observations by V a u x on the minimum temperatures reached provide data on which it is possible to deduce approximate lethal temperatures for these species, and also to consider further the suggestion already made that many of the dead fish had moved considerable distances from the area in which they had received fatal injuries.

The little experimental work that has been carried out to determine the lower lethal temperatures of fish shows clearly that for species living normally at temperatures of about 12° to 25°C. the fish are killed by temperatures well above 0°C., even if acclimatized to the lower limits of the normal range (D o u d o r o f f, 1942).

Similarly, the occurrence of unusually cold periods in warmer sea areas has resulted in extensive mortality to fish although sea temperatures had not fallen to freezing point. G a l l o w a y (1941) records extensive mortality of fish in coastal waters of Florida when the minimum sea temperature was 57°F. (14°C.). It is not correct therefore to assume that the lethal temperatures of North Sea fish are those at which the body tissues suffer mechanical damage by freezing.

In the southern North Sea, the mean minimum winter temperatures are 5°C. to 6°C. in the deeper off-shore areas, falling to about 2·5°C. along the East Anglian coast with somewhat lower values off the German and Danish coasts. The cod, whiting, and dab are to be found in coastal waters during the winter months, and temperatures below 3°C. may be experienced not infrequently by these species in one or another part of their normal habitat. The plaice, sole, and rays leave the colder coastal strip during winter months but this movement is not a great one and their normal lower limits are not likely to be more than 1°C. above those of the cod, whiting, or dab. In fact, in the Kattegat it appears that plaice are normally caught in water of temperatures at least as low as 1·1°C., since J o h a n s e n records catches of plaice in

water down to this temperature, the lowest bottom temperature experienced during experimental trawling there in 1905—7. (Johansen, 1908: Table 1, p. 13). The plaice of the Kattegat are not isolated from the North Sea stock, being an extension of that stock.

That cod and plaice can tolerate sub-zero temperatures without death is indicated by the following observations:— In late February and early March 1947, the sea water temperature, some 100 metres off-shore at Lowestoft, was below 0·5°C. for 18 days, including 7 days below 0°C., with a minimum of —0·4°C., and yet small numbers of cod continued to be caught by handlines from the piers, and there was no report of dead fish of any species being found along the coast.

Although not directly applicable, as it applies to the Arctic stock of cod, which have a lower normal temperature range, Lee (1952) reports that cod in the Barents Sea have been caught by the research ship "Ernest Holt" in water of temperatures down to, but not below, —0·6°C.

With regard to plaice, the experience of the Port Erin Laboratory is relevant. Smith (1948) reports that 43 % of the plaice in their outdoor tank survived the 1947 winter, although the water in the tank fell below 32°F. (0°C.) for two weeks and reached a mean weekly minimum of 30·5°F. (—0·8°C.).

Thus we find that for those species for which we have data (plaice, cod, whiting, and dab) the lower limit of the normal temperature range lies about as low as 1° or 2°C. and that both plaice and cod can survive temperatures just below 0°C. Thus the normal range approaches very close to the freezing point of the body fluids of these species.

The question therefore arises whether fish can survive water temperatures at or below the freezing points of their body fluids, for, if they were unable to do so, the freezing point would give the minimum survival temperature. Simpson (1908) and Britton (1924a) have shown that with moderate-sized and small fish the body temperature differs little from that of the water except when very active. Thus in the sea the body temperatures may be taken to reach virtually the same temperature as that of the water. The few experiments (Britton 1924b) on the effect of low temperatures on fish whose normal temperature range approaches zero indicate that it is only very brief exposure to temperatures below the frezing point of the body fluids that does not cause death. In these experiments no observations on the internal temperatures of the fish nor the after effects were made. Luyet and Gehenio (1938) in their review conclude that, with the exception of those fish that are affected by above-zero temperatures, fish die in the neighbourhood of their freezing points.

Dekhuyzen (1905), Dakin (1912), and Schmidt-Nielsen (1923) have shown that the freezing points of the blood and other body fluids of all teleosts examined, including cod, whiting, and plaice, lie between —0·5°C. and —0·9°C., depending to a limited extent on the freezing point of the water in which they are living. As these authors had not included soles in their observations, I made a number of

observations on the freezing points of blood of various fish including sole during trawling operations in the Irish Sea in 1953. The results are given in Table 3 and show that the freezing point of the blood of the sole also lies within the range —0·5°C. to —0·9°C.

Table 3.

Date	Time (hrs.)	Position	Depth of Water (fms.)	Sea Temp. °C.	Freezing Point of the Sea Water °C.	Fish	Freezing Point of the Blood °C.
21.3.53	1900	52°12′N., 4°42′W.	17	7·1	—1·8	a) *Pleuronectes platessa*	—0·7
22.3.53	2040	53°26′N., 3°54′W.	13	6·4	—1·71	a) *P. platessa*	—0·60
						b) *Gadus morrhua*	—0·70
						c) *G. merlangus*	—0·61
						d) *Solea vulgaris*	—0·81
						e) *S. vulgaris*	—0·80
24.3.53	0900	54°23′N., 5°47′W.	18	6·0	—1·70	a) *G. morrhua*	—0·59
						b) *S. vulgaris*	—0·51
						c) *S. vulgaris*	—0·51

The freezing point of the blood of elasmobranchs, however, varies with, and is almost identical with, the freezing point of the water in which each is living.

Summarizing, the lethal temperatures for cod, whiting, dab, and plaice probably lie between 0°C. and —0·9°C., that for sole may, but will not necessarily, lie a little higher, while that of elasmobranchs in the area cannot be tied down so precisely but may be as low as —1·5°C.

On page 161 it was stated that the numbers of reports of dead fish per hundred landings were:— sole 13·4, cod 9·1, whiting 7·1, dab 2·2, plaice 1·7, and skates and rays 0·6, which might be taken to indicate the relative values of their lethal temperatures. However, the frequency of reports is the product of a number of factors including the distribution of the fishermen in relation to that of the different species, the value of the fish, and the behaviour of the fish before and after receiving fatal injuries and, therefore, clearly cannot be used for this purpose.

Turning now to the distribution of minimum bottom-water temperatures in 1947, to see how these compare with the lethal temperatures, Vaux (1953, page 138) considers that the 0°C. bottom isotherm at its greatest extension, in mid-March, probably lay approximately in the position of the —1°C. surface isotherm found on the survey of 15.—18. February. Thus, the 0°C. bottom isotherm will have passed approximately west along latitude 54° as far as the S. 2 Buoy (see Figure 15) and then turned south for some 30 miles before curving south-east to approach the coast near Texel Island. South of 53° this isotherm was probably nowhere more than ten miles from the Dutch coast.

The reports of fishermen showed that dead fish were being caught not only in the vicinity of the cold tongue where these lethal temperatures reached the bottom, but also over a wide area where temperatures

could never have fallen below 1·5°C. There were even records of dead soles and cod from a considerable area of water of over 20 fathoms in the central Southern Bight, south of 52°30′N., where it is unlikely that the temperature ever fell below 2·5°C.

These dead fish occurring beyond the limits of lethal temperatures can only have reached these positions either by passive drift after death, as suggested by Lumby and Atkinson for 1929, or by their having received injuries due to the cold from which they later died, having swum away from the cold water or continued their normal spawning migrations during the intervening period.

The high catches of living soles at a distance from the cold tongue indicate that this species was migrating away from the cold water. The large number of dead soles caught in the Silver Pits with no dead fish of other species further supports the theory that the soles had migrated there before death, rather than that they had been carried there by the water movements. The transport of dead soles from further east would have been accompanied by the transport of dead fish of other species, but this did not occur.

The presence of dead plaice, cod, and soles to the south-west of the cold tongue cannot be due to carriage by water movements as the drift of the plankton in this area indicated a water movement to the north-east, which is in precisely the opposite direction.

Little is known of the physiological effects of cold on cold-blooded animals when it leads to death. However, for fish that can tolerate temperatures down to near the freezing point of their body fluids it may be expected that physical damage due to freezing of tissues would start on the fins and external parts and that many fish would receive a form of frost-bite of the skin and fins which might not cause death but would lay the tissues open to infection by bacteria.

The reports of pale areas on the skin of soles, and of damaged fins, would support this interpretation. Such a sequence of events would permit considerable movement of the fish between the injury by cold and their death.

It would seem probable, therefore, that the distribution of dead fish at considerable distances from the below-zero water was largely due to the continued swimming of the fish between the time of receiving injuries due to cold and their actual death.

Summary.

During January and February 1947, persistent cold easterly winds caused exceptional cooling of the water of the southern North Sea, to the extent that ice was formed extensively along the continental coast-line. Off the north-western part of the Dutch coast a tongue of cold water extended north-west from the land. In this tongue the 0°C. surface isotherm reached about 70 miles from the coast while the 0° bottom isotherm probably reached about 60 miles from the coast (see Vaux, 1953). The present paper deals with the observations made on the plankton and the fish during January—April.

The eggs of plaice, cod, and dab were found in unusually great numbers on the northern and western edge of the tongue of cold water. The spawning of plaice was prolonged. There has been no subsequent evidence that the 1947 year-class of plaice was below average, while the 1947 year-class of soles was above average.

The major effect observed of the unusual conditions on the plankton of the area appeared to be an extensive development of *Biddulphia aurita* off the north-west coast of Holland.

During February and March, large catches of cod and plaice round the edge of the cold water, and of soles somewhat further east, indicated a westerly movement of these species from the regions of most intense cooling to the east.

Throughout March and early April, dead soles, cod, and whiting were reported in considerable numbers with dabs, plaice, and flounder in smaller numbers. A few dead turbot, brill, and skate were also reported.

In the region of the cold tongue, many trawl hauls brought up only dead fish, but dead fish were also reported in varying quantities up to 120 miles south of it (the Gabbards), and eighty miles west of this region (Silver Pits).

It is suggested that the lethal temperature for most of the affected species probably lies below 0°C. and that the wide distribution of dead fish in water above 0°C. was due to continued movement of these fish between the time when they had received injuries due to the cold and their actual death.

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Net Phytoplankton at Ocean Weather Stations "I" and "J".

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Introduction and Methods.

Since the spring of 1948 the Ocean Weather Ships manning the international stations "I" and "J" in the North Atlantic have been collecting hydrographic and plankton samples while on station and during passage. Until April 1950 the two stations were manned only by the British Ocean Weather Ships "Weather Recorder", "Weather Watcher", "Weather Explorer", and "Weather Observer"; since then the Netherlands ships "Cumulus" and "Cirrus" have helped to man station "J" and have cooperated in the oceanographic work. The positions of the stations before 25. March 1950 were:— "I" 60°N., 20°W., and "J" 53°50′N., 18°40′W. Since 26. March 1950 they have been:— "I" 59°N., 19°W., and "J" 52°30′N., 20°W.

The main series of plankton samples collected while on station to the end of 1951 were hauls with the Fine International Net; this is the standard net described by Ostenfeld and Jespersen (1924), made of No. 25 bolting silk (200 meshes to the inch). Vertical hauls were made from 50 metres to the surface using the counterweight method. It was intended that hauls should be made once a week at each station, but for various reasons there are gaps in the series. Sometimes in winter the weather was too bad for the net to be used for several weeks. Table I gives the number of hauls made each month in the years 1948 to 1950.

The hauls were intended to be vertical from 50 metres, but, owing to the weather and the movement of the ships, the Officers sometimes reported considerable wire angles. There was always 50 metres of rope out and the results have been treated as if they were from 50 metres depth; it will be appreciated that there is sometimes great variation between hauls. The ships are not always exactly on station, but when the samples were taken they were nearly always within 20 miles of the stations. A few hauls in the late autumn of 1949 and 1950 were about 70 miles north-east of station "I". In drawing up the figures and tables

no account has been taken of these differences of position or of the change of station in March 1950, as there is no evidence that they make much difference to the results.

In the laboratory the catches were analysed by H e n s e n's methods using stempel pipettes. Both phytoplankton and zooplankton were counted, and the present paper deals only with the phytoplankton to the end of 1950. For diatoms normally occurring in chains the number of chains was counted and used in drawing up the results. In many cases the number of cells per chain was also counted for a proportion of the chains, but using the number of chains instead of the number of cells makes no difference to the outline of the seasonal cycles which it is intended to present here. The diatoms treated as chains are species of *Thalassiosira* and *Chaetoceras, Bacteriastrum delicatulum, Rhizosolenia stolterfothii* and *R. faroense, Thalassionema nitzschioides,* and *Nitzschia seriata.* When these methods of subsampling are used the rarer species of diatoms in the catch may not be seen; in particular the smaller species of *Chaetoceras* may have been missed in the spring outbursts.

It is difficult to use phytoplankton caught in this way for any estimate of the productivity of the waters because of the very different sizes of the diatoms, because the filtration of the net varies from haul to haul, and also because the nanoplankton is not caught. The net samples do, however, show the outlines of diatom and dinoflagellate production during the year, and this paper is concerned chiefly with seasonal cycles.

Table I. Number of Samples Examined.

	"I"			"J"		
	1948	1949	1950	1948	1949	1950
January	1	1	2	—	—	2
February	—	—	1	1	2	4
March	—	—	3	2	5	1
April	1	5	2	2	1	3
May	3	2	3	1	4	5
June	4	3	4	2	3	4
July	5	5	2	4	2	2
August	2	1	5	4	3	3
September	1	4	1	5	2	3
October	2	4	3	2	2	2
November	3	1	4	2	2	3
December	1	5	1	2	2	3

Results.

(a) Method of Presentation.

The main features of the seasonal cycles of diatoms and dinoflagellates at the two stations are shown in Figures 1 to 4 and Tables II to V. In the figures the numbers are expressed as "numbers per column"; this is the number in a column of water $^1/_5$ square metre in area and 50 metres in depth. The numbers are minimal because no allowance is made for the filtering efficiency of the net. In drawing

the figures all the observations were plotted on a logarithmic scale and smooth curves drawn through them. This method shows up most clearly the seasonal trends. In the tables the percentage composition of the diatom and dinoflagellate maxima are each calculated for a number of samples added together, the number used being given at the top of each column. It is likely that other species were present in small numbers but the subsampling methods and the time available for the work prevented their being detected.

The nomenclature is the latest in general use except that *Chaetoceras laciniosus* in this paper includes *C. pelagicum, Thalassionema nitzschioides* includes *Thalassiothrix frauenfeldii,* and *Nitzschia seriata* includes *N. delicatissima.*

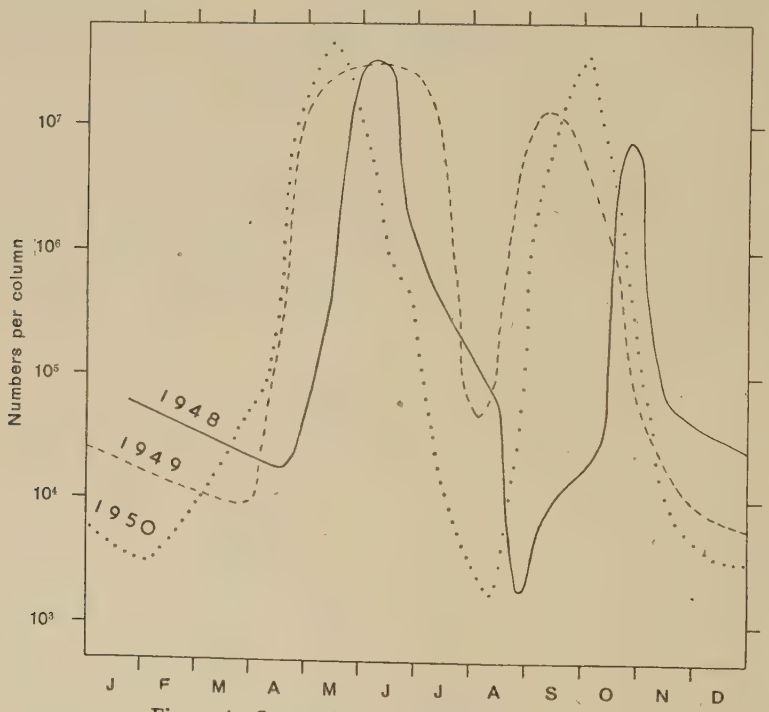

Figure 1. Seasonal cycles of Diatoms at station "I".

(b) "I".

The diatoms at station "I" show two maxima each year, one in late spring and one in autumn, with minima in summer and winter (Figure 1). In 1948 the winter condition lasted until May and then there was a rapid increase in numbers in the second half of the month. The period of greatest abundance continued until the end of June when there was a decrease to a minimum which lasted from mid-August to early October. The autumn increase took place in the middle of October and the maximum was short lived; there was a decrease in early November to the winter minimum. In 1949 the spring increase began

a month earlier, in late April, and the maximum lasted until the middle of July. The autumn increase started at the end of August, two months earlier than in 1948, and the numbers decreased in the middle of October. The 1950 spring increase was in late April, as in 1949, but the decrease from the maximum took place in June. The autumn maximum in 1950 was from early September until late October.

The highest numbers in the spring maxima were about the same in the three years, but in 1949 the outburst lasted five weeks longer than in 1950, and eight weeks longer than in 1948. There was a minimum in August in all three years. The autumn outburst in 1948 was also of shorter duration than those in 1949 and 1950, though in

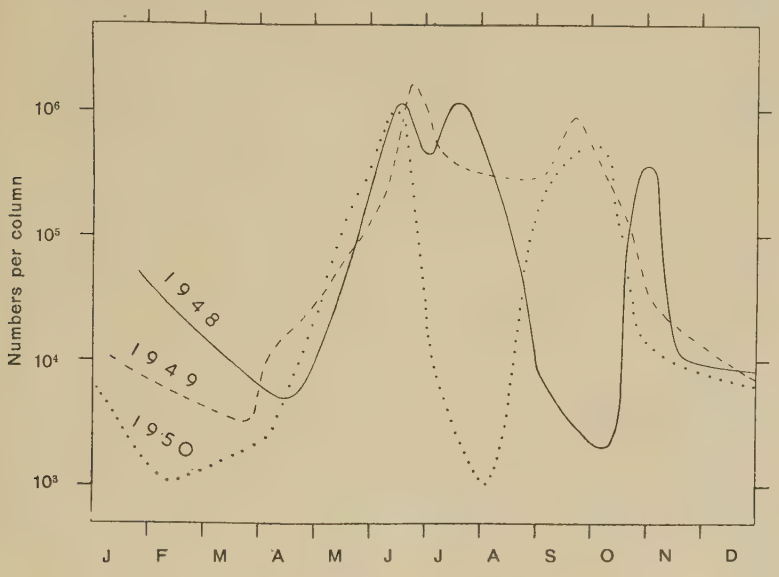

Figure 2. Seasonal cycles of Dinoflagellates at station "I".

each year the decline to the winter minimum took place at about the same time. In 1948 and 1949 the largest catches in the autumn were about half those of the spring maximum; in 1950 they were nearly equal in the two seasons.

Table II shows that the spring maxima were made up mainly of *Chaetoceras affinis, C. laciniosus,* and *Thalassionema nitzschioides. Nitzschia seriata* was important in April and May 1949 and in May 1950. In June 1950 *Rhizosolenia styliformis, R. alata, R. hebetata,* and *Bacteriastrum delicatulum* together outnumbered the *Chaetoceras* spp. In June and July 1949 there were large numbers of chains of very tiny cells of *Chaetoceras affinis* such as those described by Ostenfeld (1931) and they were responsible for the extended outburst that year. These small cells also accounted for much of the spring outburst in other years. The autumn maxima in 1948 and 1949 were composed largely of *Rhizosolenia alata,* with *Nitzschia seriata*

Table II. Percentage Composition of Diatom Maxima at "I".

	1948		1949					1950		
	May June	Oct. Nov.	Apr. May	June	July	Sep.	Sep. Oct.	May	June	Oct.
Number of samples	4	2	3	3	3	3	4	3	4	2
Coscinodiscus radiatus	+	+	+	+	+	+	+	+	+	+
lineatus	+	+	—	—	—	—	—	—	—	—
Planktoniella sol	+	—	+	—	—	—	—	—	—	—
Euodia cuneiformis	+	+	+	+	+	—	+	+	+	—
Thalassiosira spp.	+	—	+	+	+	+	—	+	+	—
subtilis	+	+	+	+	—	+	+	+	1	+
Lauderia borealis	—	—	—	—	—	—	—	—	+	—
Dactyliosolen antarcticus	+	6	+	+	+	1	1	+	+	+
mediterraneus	+	+	+	+	+	1	+	+	1	17
Leptocylindrus danicus	—	—	—	+	+	—	—	—	—	—
Corethron hystrix	+	—	+	—	+	+	+	+	—	—
Bacteriastrum delicatulum	+	+	3	1	+	+	—	2	14	6
Rhizosolenia styliformis	+	+	+	+	+	+	+	+	27	3
alata	4	80	+	+	+	40	81	2	12	3
hebetata	3	—	1	+	+	—	—	4	16	—
stolterfothii	+	+	+	+	+	+	+	2	+	1
faroense	+	—	+	+	+	+	+	+	—	+
Chaetoceras atlanticus	+	+	+	+	—	—	+	+	+	+
densus	6	+	+	+	+	+	+	+	4	+
borealis	3	+	+	—	+	—	—	+	—	—
convolutus	+	—	+	—	—	—	—	+	+	2
peruvianus	—	—	—	—	—	—	—	—	—	+
decipiens	5	+	4	6	2	+	+	2	1	2
laciniosus	27	+	18	6	4	—	—	35	+	5
affinis	23	+	39	77	83	+	+	28	15	6
debilis	—	—	—	—	—	—	—	—	—	1
Thalassionema nitzschioides	23	4	19	8	10	3	6	9	3	48
longissima	+	5	+	+	+	+	2	+	+	+
Nitzschia seriata	4	+	15	1	+	54	6	16	3	4

+ indicates present as less than 1 % of total Diatoms counted;
— no observations.

important in September 1949. In the autumn of 1950, however, *Thalassionema nitzschioides* was dominant with *Dactyliosolen mediterraneus* second in importance; unusually large numbers of *Chaetoceras* spp. were also present in October of that year.

The dinoflagellates show maxima in late spring and autumn (Figure 2). In each year there was an increase throughout May to a maximum in June. In 1948 there was a minimum from mid-August to mid-October but this was not clearly defined in 1949, and in 1950 the minimum was in July and August. As with the diatoms the 1948 autumn increase was later than in the other two years. In each year the spring maximum of dinoflagellates occurred towards the end of the

Table III.
Percentage Composition of Dinoflagellate Maxima at "I".

	1948			1949				1950	
	May June	July	Oct. Nov.	June July	July Aug.	Sep.	Oct.	May June	Aug. Oct.
Number of Samples	5	5	2	5	4	4	3	5	5
Ceratium tripos	4	17	42	10	25	14	24	2	27
fusus	50	32	21	44	34	34	25	46	29
furca	16	20	3	22	21	14	6	7	30
lineatum	2	+	2	5	2	2	2	26	1
horridum	4	3	12	6	9	6	7	2	+
macroceros	+	+	+	+	+	1	+	+	+
azoricum	+	+	+	+	—	+	—	+	+
hexacanthum	+	—	1	—	+	6	11	+	+
longipes	—	+	—	—	+	—	—	+	—
extensum	—	—	+	—	+	—	—	—	—
bucephalum	—	—	—	+	—	—	+	+	—
Peridinium crassipes	12	8	5	1	1	6	6	2	4
oceanicum	+	+	+	+	+	+	+	+	+
spp.	2	4	6	4	3	5	5	2	2
Peridiniopsis spp.	—	—	+	+	+	—	—	+	—
Dinophysis acuta	7	9	1	3	2	8	5	3	4
acuminata	+	—	+	+	+	—	+	+	—
Goniaulax spp.	1	4	5	2	+	4	7	9	1

+ indicates present as less than 1 % of total Dinoflagellates counted.

diatom maximum while the autumn maximum coincided with that of the diatoms. The main species in spring each year was *Ceratium fusus* with *C. furca* second in importance in 1948 and 1949 and *C. lineatum* in 1950. In autumn *Ceratium tripos* and *C. fusus* were of about equal importance, but in 1950 *C. furca* occurred in slightly larger numbers than either of them (see Table III).

(c) "J".

The diatoms at station "J" show a maximum in spring each year and two smaller peaks in late summer and autumn (Figure 3). In 1948 the spring increase was in mid-March with a maximum in April; there was a slow decrease in numbers to the end of June followed by a more rapid drop in numbers to the summer minimum in late July and early August. The two autumn maxima were in early September and early October; there was a decrease in October and November to the winter minimum. In 1949 the spring increase began during March and reached a maximum in early May; the decrease to the summer minimum was at the end of June. There were again two small peaks in mid-August and mid-September followed by a decline through October to the winter minimum. In 1950 the spring outburst was in April and May, the minimum was in July and August and the two autumn maxima in early September and mid-October.

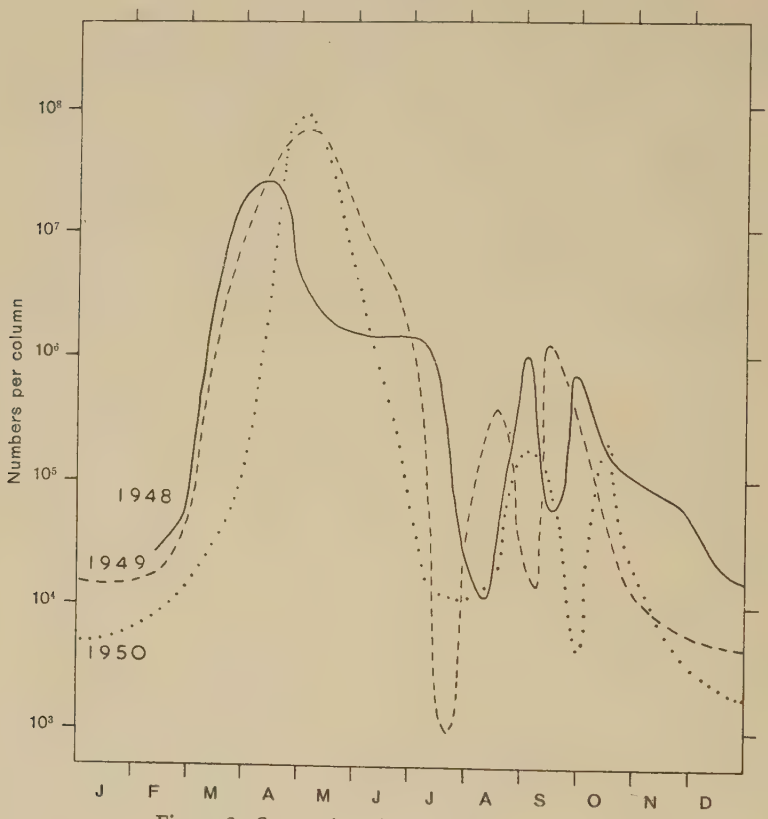

Figure 3. Seasonal cycles of Diatoms at station "J".

The spring outburst in the three years took place at about the same time but it was a month later starting in 1950 than in the previous two years and was of shorter duration. There were larger numbers at the peaks in 1949 and 1950 than in 1948. The summer minimum was at about the end of July in all three years. The separating of the two autumn peaks in each year depended on only two or three observations, but the fact that they occurred each year makes it appear that the separation is genuine and not caused by errors of sampling. The times of the peaks in 1948 and 1950 were about the same, but they were two to three weeks earlier in 1949. In 1948 and 1949 the highest numbers in spring were 20 to 50 times those of the autumn maxima, but in 1950 they were 400 to 600 times as great.

Table IV shows that the main species responsible for the spring maxima were *Chaetoceras affinis, C. laciniosus, Thalassionema nitzschioides,* and *Nitzschia seriata.* In May 1948 *Bacteriastrum delicatulum* was important and appeared again in good numbers in the spring of 1949. In June 1950 *Rhizosolenia alata* was dominant, with *R. styliformis* and *R. hebetata* of secondary importance, and there

Table IV. Percentage Composition of Diatom Maxima at "J".

	1948				1949					1950				
	Apr.	June July	Aug. Sep.	Sep. Oct.	Mar.	Apr. May	May June	Aug.	Sep.	Apr. May	May	June	Aug. Sep.	Oct.
Number of Samples	2	3	3	3	2	4	4	3	1	3	3	3	3	2
Coscinodiscus radiatus	+	+	+	—	+	+	+	2	—	+	+	+	+	—
spp.	—	+	—	—	—	+	+	—	—	—	—	—	—	—
Planktoniella sol	—	—	—	—	—	—	—	—	—	+	—	—	—	—
Euodia cuneiformis	+	+	—	+	+	+	+	—	—	+	—	+	—	—
Thalassiosira spp.	+	+	+	—	+	+	—	—	—	+	+	—	—	—
subtilis	—	—	—	—	+	+	+	—	+	+	—	+	13	4
Lauderia borealis	—	+	—	19	—	—	—	—	—	—	+	+	—	—
Dactyliosolen antarcticus	+	+	—	+	+	+	+	—	+	+	+	—	2	10
mediterraneus	—	12	—	29	+	+	+	+	—	—	+	—	—	—
Leptocylindrus danicus	—	—	—	—	+	+	—	—	—	—	—	—	—	—
Corethron hystrix	+	+	—	—	—	+	+	—	—	—	+	—	—	—
Bacteriastrum delicatulum	31	5	—	—	9	8	2	—	—	+	5	—	—	—
Rhizosolenia styliformis	+	7	2	3	+	+	+	+	+	+	+	7	8	8
alata	+	+	93	26	+	+	+	96	91	+	+	89	63	77
hebetata	+	+	—	—	+	+	+	—	—	+	4	2	12	+
imbricata var. *shrubsolei*	+	+	—	—	+	+	+	—	—	—	+	+	—	—
stolterfothii	+	+	—	—	+	+	+	—	—	4	+	—	—	—
faroense	—	+	—	—	—	—	—	—	—	+	—	—	—	—
Chaetoceras atlanticus	1	+	—	—	+	+	+	—	—	+	2	—	—	—
densus	5	1	—	+	1	+	+	—	—	+	+	—	—	—
borealis	2	+	—	—	+	+	—	—	—	—	—	—	—	—
convolutus	—	—	—	—	+	+	—	—	+	—	+	—	—	—
peruvianus	—	—	—	—	—	—	—	—	—	+	+	+	—	—
decipiens	3	7	+	+	11	5	5	—	—	+	+	—	—	—
laciniosus	6	10	+	+	23	9	8	—	+	11	23	—	—	—
affinis	33	5	—	—	20	51	67	—	+	8	23	—	—	—
Thalassionema nitzschioides	5	43	3	8	11	20	13	+	6	24	15	—	—	—
longissima	+	3	+	11	+	+	+	—	2	+	+	+	+	+
Nitzschia seriata	10	3	+	2	21	6	5	—	—	50	23	—	—	—

+ indicates present as less than 1 % of total Diatoms counted.

were few other diatoms present; this is similar to what happened at "I" in that month. As at "I" the cells of *Chaetoceras affinis* were very small and they were particularly responsible for the long spring outburst in 1949. The autumn maxima in each year were almost completely made up of *Rhizosolenia alata.* The second autumn peak in 1948 also contained many *Dactyliosolen mediterraneus, Lauderia borealis,* and *Thalassiothrix longissima,* while in 1950 *Thalassiosira subtilis* was of secondary importance in the first maximum and *Dactyliosolen antarcticus* in the second. In autumn 1949 *Rhizosolenia alata* was completely dominant but the first maximum was composed of *forma gracillima* and the second of *forma genuina.*

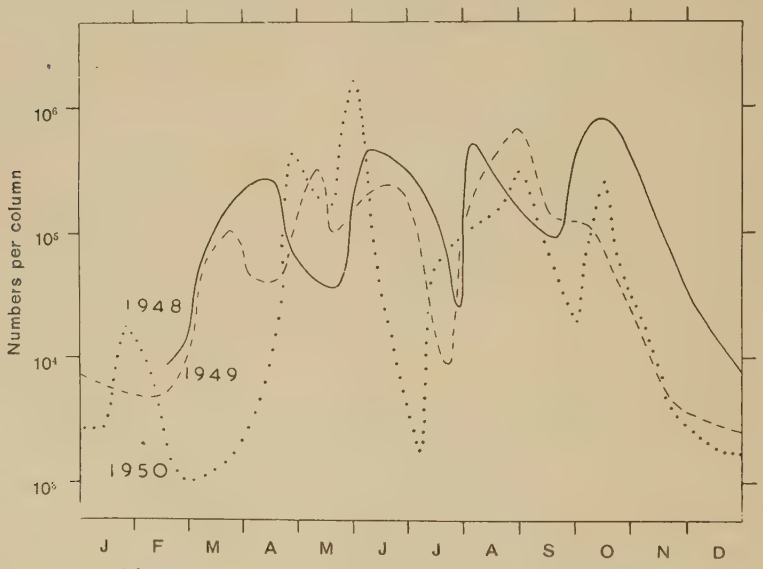

Figure 4. Seasonal cycles of Dinoflagellates at station "J".

The dinoflagellates show four maxima between the middle of March and late October in each year but they are not very clearly defined (Figure 4). In each year there was a minimum in July. *Ceratium fusus* was the commonest species in spring with *C. tripos* and *Peridinium crassipes* in 1948, *Ceratium furca, C. tripos,* and *Goniaulax* spp. in 1949, and *Ceratium lineatum* in 1950, as at "I". In summer and autumn *C. tripos* was important with *Goniaulax* spp. and *Ceratium fusus* in 1948, *C. fusus, C. hexacanthum,* and *Peridinium crassipes* in 1949, and *Ceratium fusus* and *C. furca* in 1950 (Table V).

Discussion.

A comparison of the two stations shows that the spring diatom outbursts are similar in intensity at both stations, but the increase is earlier at the southern station "J". In 1948 it was nine weeks earlier,

Table V. Percentage Composition of Dinoflagellate Maxima at "J".

	1948				1949			1950			
	Apr.	June July	Aug. Sep.	Sep. Oct.	Apr. May	May June	Aug. Sep.	Apr. May	May June	Aug.	Oct.
Number of Samples	2	5	5	3	4	4	5	3	4	3	2
Ceratium											
tripos	3	28	47	15	3	18	28	1	+	14	36
fusus	29	30	14	18	21	31	16	43	33	41	41
furca	9	8	4	4	33	16	8	5	4	24	15
lineatum	+	10	2	+	6	5	2	30	53	+	+
horridum	4	2	+	+	4	3	3	4	1	3	1
macroceros	2	3	2	+	—	—	2	+	—	+	—
azoricum	2	2	—	+	3	4	+	2	+	+	—
hexacanthum	+	2	8	+	—	2	15	+	+	+	—
extensum	—	+	—	+	—	—	+	—	—	+	+
bucephalum	—	—	+	+	+	+	—	+	+	1	1
platycorne	+	—	—	—	—	—	—	—	—	+	—
buceros f. *molle*	—	+	—	—	—	—	—	—	+	—	—
gallicum	—	—	—	—	—	—	+	—	—	—	—
Peridinium											
crassipes	41	6	7	12	2	1	10	+	+	12	—
oceanicum	+	+	+	+	4	1	—	+	+	—	—
spp.	—	—	—	—	12	3	8	11	4	3	3
Peridiniopsis											
spp.	+	—	+	+	3	+	+	+	+	—	—
Dinophysis											
acuta	1	—	1	+	3	1	+	1	+	2	+
caudata	—	—	—	—	—	—	—	—	—	+	—
Goniaulax											
spp.	8	9	13	47	5	15	6	+	2	+	—

+ indicates present as less than 1 % of total Dinoflagellates counted.

in 1949 five weeks, and in 1950 two weeks earlier. At both stations 1949 was the year in which there were most diatoms during the spring season; the largest catches were recorded in 1950 but over a shorter period than 1949. At "J" the summer minimum is of shorter duration than at "I". There are two autumn maxima at "J" compared with one at "I" and both have smaller numbers of diatoms than the autumn outburst at "I". In 1949 and 1950 the two peaks at "J" occurred at the same time as the one at "I" but in 1948 "I" was later than "J". The decrease to the winter minimum takes place about two weeks earlier at "J".

In general the same species are responsible for the diatom maxima at both stations; *Chaetoceras affinis, C. laciniosus, Thalassionema nitzschioides,* and *Nitzschia seriata* are most important in spring, and *Rhizosolenia alata* in autumn. There is usually a greater variety of diatoms present at "J" than at "I" in spring, but more species at "I" than at "J" in autumn. The same species of dinoflagellates are also important at both stations, *Ceratium fusus* being the most numerous, with *C. tripos* and *C. furca* nearly as important. As with the diatoms

there are few more species present at "J" and these are usually warm-water species.

The time of onset of the spring increase depends mainly on the stabilization of the surface water layers and on the amount of light available for photosynthesis, and the intensity of the outburst will depend on the supply of nutrient salts. The differences between the two stations and the three years probably depends on differences in the time of stabilization after the winter. Unfortunately there are insufficient hydrographic data available to calculate the stability, nor are there any nutrient salt data for the two stations. The stabilization depends to some extent on the winds; mean wind strengths for the two stations for 1948 and 1949 are presented by Gordon and Barlow (1952). The main things which their Figure 7 show are that the winds generally decrease between March and June, that in early spring "I" is windier than "J", and that the late summer of 1948 was windier than that of 1949 at both stations. The stronger winds at "I" in spring may be partly responsible for the later spring increase in phytoplankton there.

Information on the surface temperature at the two stations is given by Rodewald (1952a and 1952b) and Gordon and Barlow (1952). Rodewald gives monthly mean sea surface temperatures for the two stations based on all previous observations, and presents monthly anomalies from 1948 to 1951. Station "J" is 370 miles south of "I" and the mean surface temperature is about 2°C. higher throughout the year. At "I" the temperature from December to April is between 8°C. and 9°C. while at "J" it is between 10°C. and 11°C.; at "I" in July and August the surface temperature is between 12°C. and 13°C. and at "J" it is between 14°C. and 15.5°C. At "I" there was a positive anomaly for most months in 1948, 1949, and 1950, with the highest ones in the autumn of 1949 and the summer of 1950. At "J" there were positive anomalies from the autumn of 1948 to spring 1950 and negative ones for the rest of 1950. Rodewald (1952b) deduces from the positive anomalies at "I" and the negative ones at "J" in late 1950 and in 1951 a southward displacement of the North Atlantic Drift.

The currents in the North Atlantic will bring different water masses and populations of plankton to the two stations; it had been assumed that these populations would be carried from "J" north-eastwards and that a branch of the current would take some of the water past "I" towards Iceland. Gordon and Barlow (1952) state that at "J" the vector mean current for November 1947 to July 1948 was 7.3 miles per day, N 55° E, and for 1949 it was 2.9 miles per day, N 67° E. This is in agreement with the general direction of current in this region shown in current atlases. At "I", however, the vector mean currents were 3.5 miles per day, S 72° E, for the year 1948 and 7.3 miles per day, S 70° E, for the year 1949. This direction, which is constant, is, the authors say, "a new and hitherto unsuspected one". It is not clear what effect these currents have on the plankton

populations at the two stations. The small differences in the species representation in the phytoplankton are probably due to the higher temperatures at "J", where more warm water species are found, and these might be brought in from the south-west. The few species found at "I" and not at "J" are colder water species, such as *Ceratium longipes,* which might well have been carried in from the north-west. More obvious differences may be found when the longer-lived zooplankton is examined.

Previous investigations of phytoplankton in the North Atlantic south of Iceland are reported by Steemann Nielsen (1935 and 1943) and Hentschel (1936). Steemann Nielsen (1935 and 1944) says that in the Gulf Stream area south of Iceland over deep water the phytoplankton only begins to reproduce at the end of May when production is active for a month, that plankton production for the rest of the summer is very poor, and that there is no autumn increase in production. This statement is based mainly on the "Dana" collections of phytoplankton from water samples collected at stations about 62° 30′N. in 1932, 1933, and 1934, and on Hentschel's work in the "Meteor" in February and March 1935 in the same area. Station "I" is 200 miles south of this area. The present investigations confirm the outburst in late spring but show that diatom production in at least two years (1949 and 1950) can begin a month earlier than late May and that it lasts longer than one month; also that there is a pronounced autumn production in September and October and even into November (1948). This autumn production would be missed by the "Dana" whose sampling in the area ended early in September. Unfortunately, the present results cannot be compared quantitatively with the "Dana" water samples, and the nanoplankton, which, Steemann Nielsen states, forms "almost exclusively" the plankton of the open sea, is not caught in the nets.

No previous series of observations have been made at stations near "J". The earliness of the spring increase here compared with "I" is similar to that found by Hart (1942) in comparable latitudes in the southern hemisphere. Hart's regions are not based solely on latitude but "J" would be in his "Northern Region", in which the spring increase takes place in October to November (equivalent to April to May) with the maximum in December (June). "I" corresponds with the northern part of Hart's "Intermediate Region", in which the increase is in late November and December (May and June) with the maximum in January (July). Hart says that "in the southern hemisphere with its very much lower temperature in corresponding latitudes the increase takes place later in the year". But comparison of these oceanic areas shows that there is less than a month difference between northern and southern hemispheres. There are also autumn increases in both hemispheres, those in the south corresponding in scale to those at "J".

Hart also reports that the main increase in the neritic areas in the southern hemisphere, such as in the South Georgia area, takes place earlier than in the oceanic regions in the same latitude. A similar

condition is found in the northern hemisphere. Gran (1929 and 1930) found that the spring increase in Norwegian coastal waters started in March, some weeks earlier than in the offshore waters, and at "I" in about the same latitudes it is also one or two months later. Marshall and Orr (1927 and 1930) found that the spring increase in the Clyde area begins regularly towards the end of March and reaches a maximum in early April. Harvey and others (1935) found that in the English Channel the spring increase started in February and reached a maximum in March. "J" is in latitude between the Clyde and the Channel and has the maximum in late April or May, also showing the later increase in oceanic areas.

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The Selectivity of Different Fishing Gear used in Lofoten.

By

Gunnar Rollefsen.

The oldest of the fishing gears still in use in Lofoten is that employing a single hook — a handline furnished with a heavy stone or iron sinker and a special device to keep the hook free of the line. The hook is fairly large and has a bright coating of cast lead or pewter in the form of a small fish, and, as a rule, a piece of white fish-skin is fastened to the hook.

This gear is operated in the following way. By means of the line the sinker and the hook are lowered to the depth at which the fish are known or supposed to be. The fisherman then takes a double turn of the line round his fist and starts fishing by hauling a fathom or so of the line slowly but vigourously over a roller attached to the rail. After each upward pull the hook is allowed to sink again, so that the hook continually rises and sinks through about a fathom of water. A fish trying to catch the bait may be hooked in any region of the body. The success of this gear depends accordingly on the interest which the fish pays to the bait.

The longline, which was introduced to Lofoten in 1580, carries a large number of hooks baited with herring or mussels. The line may rest on the bottom or be kept at a certain depth by means of floats. The success of this gear also depends on the activity of the fish.

The use of nets in Lofoten dates from about 1650. A varying number of nets are joined to form a fleet. The nets may be used as bottom nets or float nets anchored to remain a certain distance above the bottom. The meshes of the nets are of a size corresponding to the average size of the fish. However, as the average size of the fish may change from year to year the fishermen when buying or making new nets try to choose a mesh width in accordance with their experience of the preceding year. With nets too, it is the activity of the fish which determines the success of the gear.

Our biological statistical investigations for the Lofoten cod — carried on since 1913 — are based on the catches taken by these 3 different types

of gear. When comparing the size distribution, age distribution, and sex ratio of the fish taken by hooks or nets, we may note a very striking and stable difference which persists from year to year. Fish caught on single hooks or longlines are very much alike; the net-caught cod, however, are different.

Firstly, the net-caught cod are bigger. The explanation may be very simple. The net-fishermen want, of course, the largest possible catch, that is, the highest possible number of big fish. They therefore choose a mesh size which they think will give them this result, one which allows the big fish to become enmeshed but which is at the same time small enough to retain the more abundant fish of average size.

Secondly, we find a difference in the sex ratio. The sex ratio for hooks is 40 % males to 60 % females; for nets it is 60 % males to 40 % females. Of this also we are able to give a reasonable explanation. It is obvious that the male cod is much more active than the female during the spawning time. From observations in aquaria we learn that it is the male cod which is the more aggressive. When on the fishing banks in Lofoten, where thousands of nets run in all directions and create a veritable labyrinth, a roaming fish is in much more danger than a fish which remains in one place. Accordingly the activity of the male sex may be the reason for the high percentage of males caught by net. On the other hand, a female fish just hovering about, with no fixed aim, no pronounced urge, may very well not only avoid the risk of running into a net, but also have time to investigate objects which might be edible. This may be the reason why the females are more frequently found on lines.

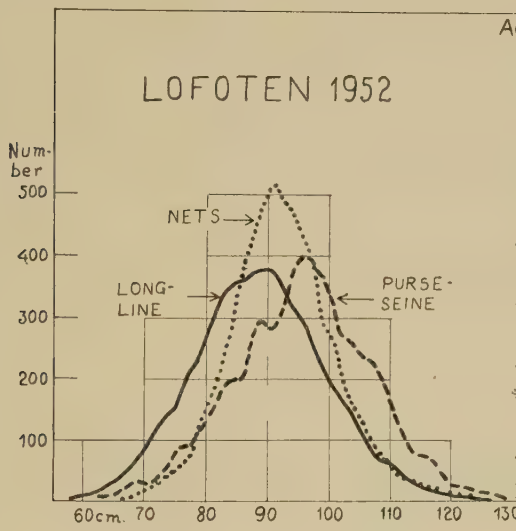
From these differences in size distribution and sex ratio it is obvious that the gears work selectively, and the picture of the stock which appears from what the fishing gears bring to the surface must be more or less inadequate. We assumed, however, that the line-caught cod gave a better picture of the shoals than the net-caught cod, because the net obviously takes only the size of fish permitted by the mesh.

The value of catches by nets as a basis for biological statistics must therefore be limited. But the catches from longlines must also be regarded as selected, for two main reasons, one of which is the predominance of females on longlines and the other is the fact that mortality rates calculated from longline catches show a higher mortality for the younger age-groups than for the older. However, as the material from longlines was the best we could get and as the results from year to year seemed to be of a stable nature, our ideas and theories were not upset — until the purse seine made its appearance in Lofoten.

The purse seines used in Lofoten work in the usual way, except that they are lowered to a depth of 20-30 fathoms below the surface and hang from lines attached to canvas buoys on the surface. This gear takes no account of whether the fish is hungry or dejected, male or female, or whether it is large or small. The circular curtain of the purse seine sinks down and cuts out a portion of the shoal of fish and brings it up without any prejudice as to sex or size. As far as I can see we have good reason to believe that the purse seine gives us a correct, or nearly correct, picture

of the fish present. But we have to bear in mind that the fish may have a tendency to stratify or segregate themselves with respect to size, sex, or stage of maturity. Our confidence in the purse seine catches is, however, strengthened by the fact that the sex ratio in them seems to be 50-50.

If we regard the size and age distribution of the cod from the purse seine as representative of the fish present, it may be of interest to compare the age and size distribution of cod caught by the other types of gear (Figure 1).



Age	P-S	L.L.	N.
6	—	0.10	0.09
7	0.62	2.18	0.72
8	5.14	9.07	3.98
9	25.45	37.15	27.22
10	31.16	29.85	32.95
11	18.47	13.33	20.30
12	6.17	3.72	6.91
13	2.54	1.20	2.00
14	1.77	0.54	1.21
15	4.62	1.18	2.13
16	1.39	0.62	0.71
17	1.15	0.40	0.37
18	0.68	0.29	0.75
19	0.61	0.26	0.55
20	0.10	—	—

Figure 1.

If we compare the relative number in each length-group of fish caught by line and purse seine, we find that the lines catch 5 times as many cod belonging to the 70 cm. group as the purse seine, and twice as many fish of 80 cm. length. The smaller size-groups have a very pronounced tendency to be caught on longlines, while on the other hand the larger size-groups are under-represented in line catches compared with those from the purse seine.

The nets, however, select the fish in yet another way. There is with them a deficiency of the smallest and largest fish and an excess of the intermediate size-groups. The small fish pass through the meshes and the big fish cannot enter them. A small cod is, as a rule, a young cod and if we now turn to the age distribution of fish taken by the three different gears (Figure 1), we get the same picture — the younger the fish the higher is the percentage caught by line. (We can think of many reasons for this. Young fish may pay more attention to food than the older ones, their interest apparently decreasing gradually with increasing age.)

The age distribution of the net-caught cod does not differ very much

from that in purse seine catches so far as the youngest age-groups are concerned, in spite of what we found for the length distribution. This is quite natural, because the smallest cod of the younger year-classes escape.

Is this segregation which results in a selection of certain size-groups and age-groups in some way or other connected with the number of spawnings performed? We know that the shoals of spawning cod in Lofoten consist both of fish propagating for the first time and also of fish which have made one or more spawning migrations before. The percentage of first-time spawners is high for the fish caught by line and lower for both net and purse seine. This is in accordance with the predominance of young fish caught by line. But we shall be disappointed if we hold the theory that this predominance is due solely to the appetite or ignorance and innocence of the first-time spawners. The tendency of the cod to be caught by line decreases with increasing number of spawnings and the fish also seem to be able to keep clear of the nets more and more effectively.

As was pointed out in a paper by Mr. G. D a n n e v i g, these findings also offer a solution to some problems met with in connexion with the tagging experiments in Lofoten.

The purse seine has demonstrated the existence of a group of fish which has been naturally protected against longlines and nets by their large size and by their behaviour. It will be very interesting to follow the fate of this reserve of old fish in the years to come, now that we have introduced gear which apparently takes as heavy a toll of these as of the younger fish. The number of purse seines in Lofoten amounts to 800, and the quantity of cod caught by purse seine in 1952 was about 60 % of the total catch. It is an experiment on a big scale which has now been started and which concerns one of the most important stocks of fish in the northern hemisphere.

Tagging Experiments on Cod, Lofoten 1947—1952:

Some Preliminary Results.

By

Gunnar Dannevig.

Since 1947 tagging experiments have been carried out annually on the cod occurring on the Lofoten Banks during the spawning season. The purpose of this work is, *inter alia*, to get an idea of the extent to which the fishermen exploit this stock of fish. When such problems are being studied, it is of importance to minimize experimental errors as far as possible. The fish may suffer fatal injuries during the tagging process; they may lose the tags; or the tags may not be observed by the fishermen, or not returned. Perhaps also the fact that a fish is carrying a tag in the gill-cover may increase its chances of being captured by nets.

There is also another point of no less importance. The results obtained for the fish used in our experiments are of no general application unless these fish are really representative of the stock. This requires, amongst other things, that the fish do in fact behave normally after tagging; any abnormal behaviour due to the tagging process may well influence their chances of being captured.

Some of the fish used for our experiments were caught by handline. Most of the fish caught by this type of gear were in good condition and not badly hurt. During the last three seasons, however, we tagged cod taken by purse seine exclusively, and the fish caught by this gear generally seem to be in excellent condition, provided the catch is not too large and is handled carefully. Nevertheless, there are always some fish caught by both these methods which have to be discarded because they have suffered injuries which may be fatal. For instance, some specimens do not tolerate the changes in hydrostatic pressure.

Several types of tags have been tried (see Figure 1). These are:—

Black ebonite disks
White celluloid disks
Yellow plastic disks with a black triangular section
Strap tags
Hydrostatic tags, a small and a large type.

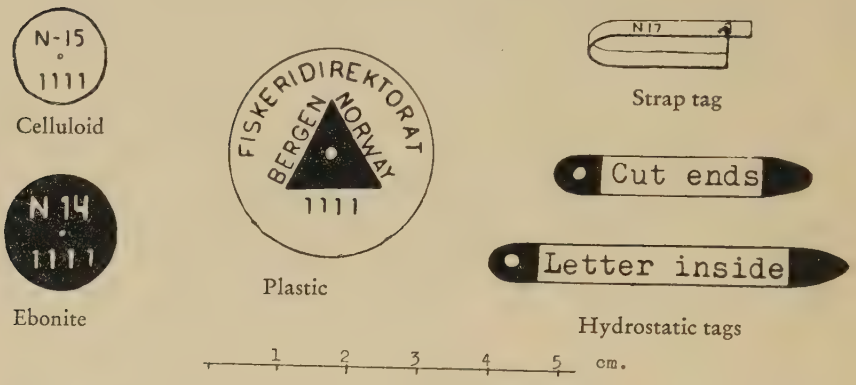


Figure 1. The various types of tags used on the Lofoten Banks.

The various types of buttons and the strap tags have always been fixed to the gill-cover, the former by a pure silver wire (diameter 1.2 mm.). The method used to attach the hydrostatic tags has been varied to some extent (Figure 2). They have been fixed by stainless-steel wire (diameter 0.6 mm.) either to the gill-cover, or between the 2nd and 3rd dorsal fins. In the years 1950—1952 we also employed nylon line. With a curved needle, the hydrostatic tags can be attached before the 1st dorsal fin, or between the 2nd and 3rd dorsal fins.

Table 1. Cod tagged on the Lofoten Banks in 1947.
Percentage recapture for each type of tag during the period May 1947—August 1952.

Black ebonite disks	6.6 %
White celluloid disks	2.6 %
Strap tags	1.5 %
Hydrostatic tags	25.0 %

The numbers of the various types of tags returned differ considerably, as appears from the 1947 experiment (Table 1). The percentage recovery is 25 % for the hydrostatic tags against 1.5 % for the strap tags. A more detailed analysis shows that the strap tags are overlooked by the fishermen to a greater extent than are the other types. We also find definite indications that the buttons fixed in the gill-cover are shed to a greater extent than are the hydrostatic tags. In later experiments

we also obtained the best results with the hydrostatic tags, and since 1950 we have used that type only.

Some of our results indicated, however, that it was necessary to study the method of tagging in relation to the type of gear used by the fishermen. The principle gears used on the Lofoten grounds are nets, longlines, and handlines. Since 1950 the purse seine has also been used. Our statistical records show the weekly catches taken by each type of gear. It soon proved that of the tags which were recovered during the tagging season, an unexpectedly high proportion was returned from catches taken by nets. The problem arose whether some fish might be recaptured by the nets because they were carrying a tag in the gill-cover, the tag catching in the meshes of the net.

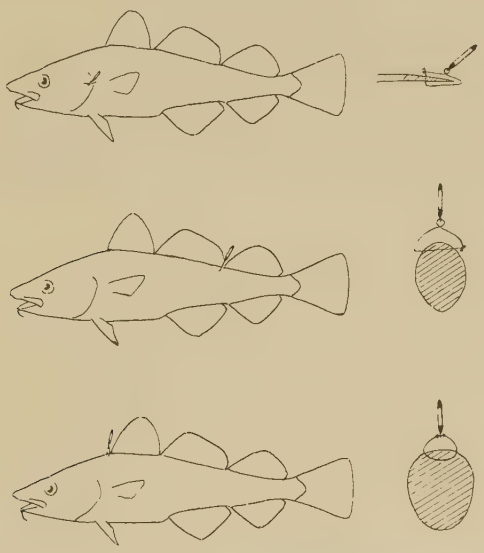


Figure 2. The methods used to attach the hydrostatic tags.

A more detailed analysis showed, however, that yet another phenomenon had to be considered. The relative numbers of tags returned from catches taken by the different types of gear were found to vary according to the time elapsed between tagging and recapture. In Figure 3 the fish recaptured by each type of gear are classified according to the number of days which have elapsed since tagging. It is especially during the first 5 or 10 days that the nets take so many of the tagged fish. The catches taken by handlines and longlines yield more regular numbers throughout the season.

In order to explain these observations we have to consider the behaviour of the fish. The cod on the Lofoten Banks may sometimes move so little that the nets take only small catches. As soon as the fish begin to swim more actively, they are more liable to be caught by this gear. The tagging process may well influence the behaviour of the fish in this

way, especially since they have been exposed to considerable changes in hydrostatic pressure. If this is the case, the number of fish recaptured shortly after tagging must be regarded with some caution.

The data indicate, however, that the fish gradually resumes its normal behaviour, and we may assume that a tagged cod revisiting the Lofoten Banks after 1 year or more really behaves normally. In the 1949 season

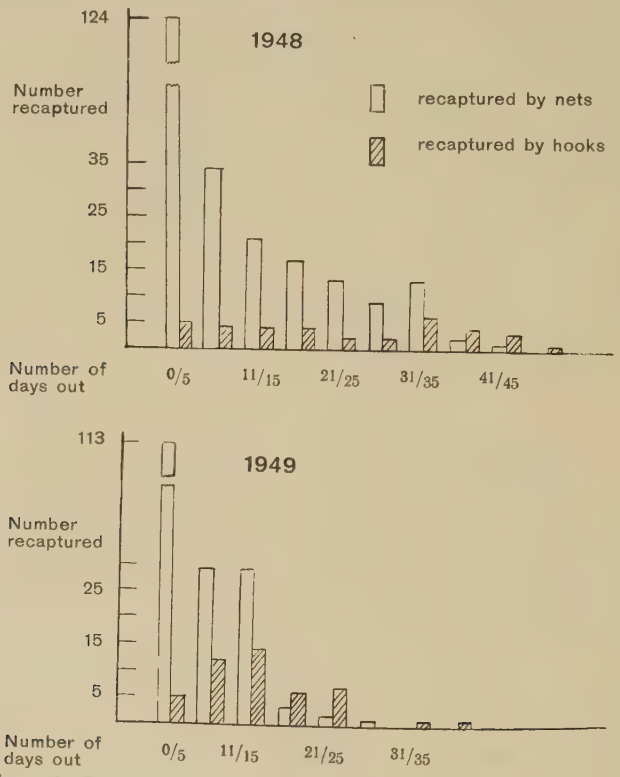


Figure 3. Recaptures by number of days after tagging.

150 specimens from the experiments in the two previous seasons were recaptured. Excluding 4 specimens for which the type of gear was not stated, 74 % were returned from catches taken by nets (Table 2). During that season the nets did not take more than 50 % of the total catch. Thus this type of gear seems to account for an unduly high proportion of the tags returned, even when the fish has lived one year or more after tagging.

We cannot therefore exclude the possibility that some of the tagged fish are recaptured by nets because they are carrying a tag in the gill-cover. The results of some experiments carried out in 1949 also indicate that this really is the case. The hydrostatic tags were fixed alternately in the gill-cover and between the dorsal fins by stainless-steel wire.

Table 2. Cod tagged on the Lofoten Banks in 1947 and 1948. Number recaptured within the same area in 1949 by each type of gear.

	Recaptured		Catch	
	Number of fish	%	1000 tons	%
Total	146	100	66.7	100
by nets	108	74	33.1	50
by hooks	38	26	33.6	50

During the same season approximately the same numbers of the two series were returned from the catches taken by longlines and handlines (Table 3). The nets, however, took considerably more of the fish with tags fixed in the gill-cover than of those with tags fixed dorsally.

Further experiments were planned in order to elucidate these problems. In 1950 we tried fixing the hydrostatic tags by ordinary nylon fishing line. With this material it is possible to attach the tags in a way which eliminates the possibility of a fish being recaptured by the nets because of the tag itself. During the last three seasons (1950—52) the hydrostatic tags were fixed to the fish by three different methods, viz.:—

1) In the gill-cover by stainless-steel wire
2) between the 2nd and 3rd dorsal fin, by similar wire
3) dorsally by nylon.

These methods were used simultaneously throughout the tagging period. For each of these series the total number of tags returned from the Lofoten Banks was classified according to the type of gear by which the fish was taken (nets, longlines and handlines, purse seines). The proportion of tags returned from the catches taken by each type of gear was calculated as a percentage of the number liberated within each series, the results being shown in Figure 4.

The fact that a fish is carrying a tag cannot influence its chances of being captured by a purse seine. We shall, therefore, first consider the number of tags returned from the catches taken by that gear. It appears that in all experiments the tags fixed dorsally by nylon have been most frequently returned.

As regards the fish recaptured by longlines and handlines, the various methods have on the whole yielded very much the same results.

Among the tags returned from catches taken by nets, those fixed to the gill-cover by wire are relatively more numerous than those fixed

Table 3. Cod tagged and recaptured on the Lofoten Banks in 1949.

Method	Number tagged	Number recaptured total	by nets	by hooks
Hydrostatic tags fixed in gill-cover	466	61	46	13
Hydrostatic tags fixed dorsally	464	40	21	15

dorsally by nylon, but the difference is not great. It is observed in all experiments, however, and is presumably significant therefore.

The difference between the results obtained by the various methods may be explained in several ways. There are, perhaps, different rates of shedding. The number of tags overlooked or otherwise lost may depend both on the method used for attaching the tags, and on the method of fishing. Judging from the results hitherto obtained we cannot

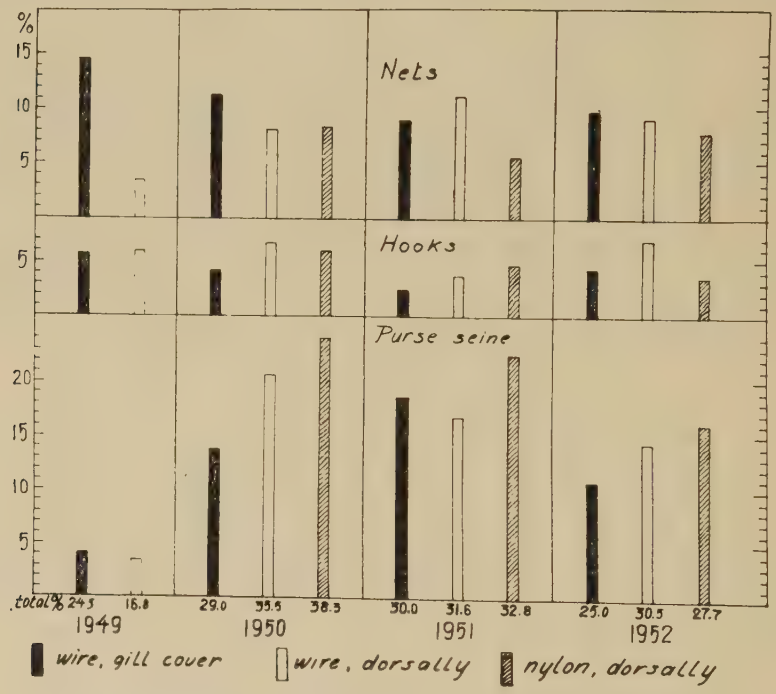


Figure 4. Experiments with the hydrostatic tag, Lofoten 1949—52. The percentage retaken on the Lofoten Banks by each type of gear.

exclude the possibility that in some rare cases we may get artificial recaptures by nets because the fish is carrying a tag fixed by wire to the gill-cover. I would like to stress, however, that the difference between the various methods is greatest in the case of the catches taken by the purse seine. This gear cannot select the tagged fish in any artificial way.

As regards the total number of tags returned from the Lofoten area, those fixed dorsally by nylon have generally been most frequently returned (Figure 4). We have, therefore, no reason to assume that any of these methods has given too high a percentage of recapture owing to our method of tagging.

We will now return to the problem of the reason for the great difference in the relative numbers of tags returned from the various gears. The results obtained on the Lofoten Banks during the seasons 1950-52

are given in Figure 5. The columns indicate the number of tags returned from a catch of 1000 tons taken by nets (black columns), longlines and handlines (open columns), and purse seines (shaded columns).

The nets, longlines and handlines are used throughout the season, from about 1. February to 20. April. In all years considerably more tags have been returned from the catches taken by nets than from catches taken by hooks. The difference is very great, and cannot be explained by errors in method.

The purse seine is generally used during the latter half of the season, from about 10. March onwards. The catches taken by this gear have yielded nearly the same number of tags as have the catches taken by nets. During this period also we have had only few tags from the catches taken by longlines and handlines.

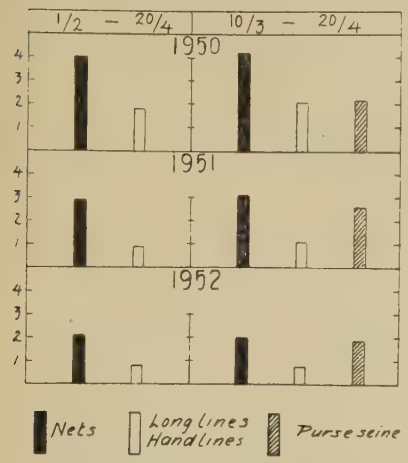


Figure 5. Cod recaptured on the Lofoten Banks 1 year or more after tagging. Number of tags returned from a catch of 1,000 tons taken by the various types of gear.

The differences here observed cannot be considered as accidental or as having been caused by our method of tagging; we have probably to do with quite another phenomenon. The stock of cod on the Lofoten Banks is not homogeneous. R o l l e f s e n (1) has shown that the recruit spawners are very numerous; they constitute on an average nearly 50 % of the catches taken by longlines. There are different runs of fish; for instance, the recruit spawners generally arrive later in the season than do the older fish. Furthermore it is a matter of experience (and has been demonstrated by R o l l e f s e n (1)) that the fish taken by the various types of gear differ in average size and age. The largest fish are taken by the purse seine, the smallest by the longlines. The recruit spawners are relatively most numerous in the catches taken by longlines and handlines. These types of gear will, therefore, not take so many of the tagged fish as do the nets and purse seines. The fish which have been recaptured on the Lofoten Banks one year or more after tagging have spawned at least once before.

It was of importance to discover whether the various types of gear made a similar selection according to size of the fish tagged. For all the fish

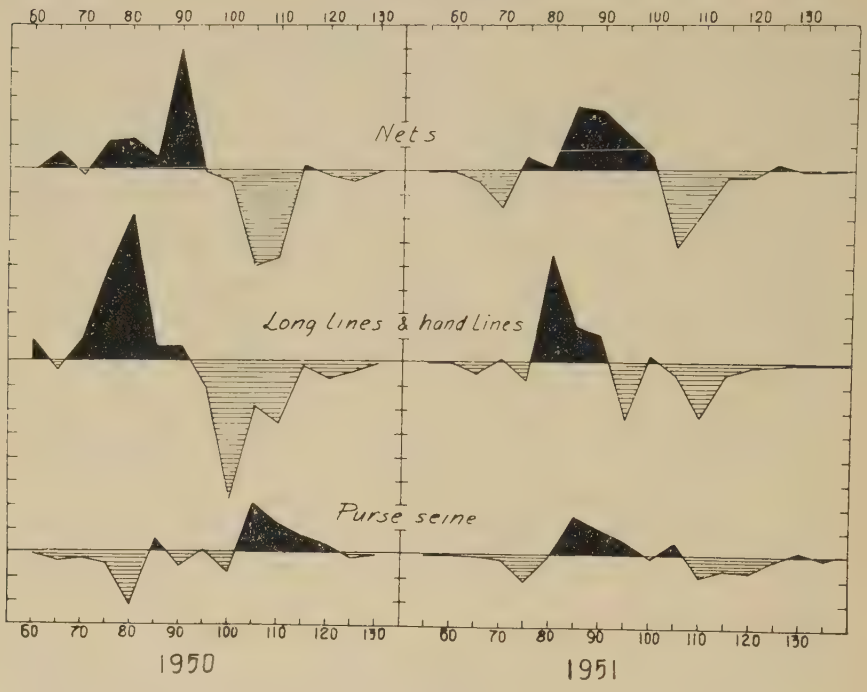


Figure 6. Cod tagged and recaptured on the Lofoten Banks.
Size differences between the fish liberated and those retaken by each type of gear.

liberated in each experiment the size distribution was calculated, and similar size distributions were calculated for the fish recaptured on the Lofoten Banks by each type of gear, according to their size when liberated. The differences between these two size distributions are given in Figure 6 for the 1950 and 1951 experiments.

It appears that the nets took relatively most of the 90 cm. size-group. The longlines and handlines made a marked selection of somewhat smaller fish, of about 80 cm. The purse seine seems to have taken the most representative samples of the tagged fish; the differences between the sizes of the fish liberated and of those recaptured are much smaller for this gear than for the others.

When the results of our experiments are considered, it must be borne in mind that the stock of fish visiting the Lofoten Banks in a particular year is not representative of the stock occurring on the same banks during the following season. That applies to fish whether tagged or not. It must be assumed, however, that the results of the experiment in one season will give adequate information about the fate this stock will meet. If 20 % of our tags are returned within one year, we may assume that at least 20 % of the stock is taken by the fishermen during that period.

Thus the number of fish recaptured from the experiments in a single season may be used to estimate the extent to which the fishermen exploit

the stock which has visited the Lofoten Banks during that year. It has been found necessary, however, to eliminate the fish which have been retaken on these grounds during the same season. The number recaptured during this period is much influenced by the date and locality of liberation, and perhaps also by abnormal behaviour of the fish due to the tagging process. The percentage recaptured during the following period was then calculated on the basis of the number unaccounted for at the end of the tagging season. The results obtained with the hydrostatic tags are given in Table 4.

Table 4. Percentage of tags returned up to August 1952 from tagging experiments on the Lofoten Banks.

Year of tagging:	1947	1948	1949	1950	1951
Percentage of recapture:	25.0	39.9	22.0*	35.6	12.4

*) Some of the tags defective.

It appears that the number of fish recaptured is not small, being up to 40 %. These results indicate that the fishermen take a considerable proportion of the cod which have spawned once on the Lofoten Banks. This implies that the output of the fishery must be closely related to the size of the stock, which is in accordance with the results previously obtained by R o l l e f s e n (2) from other considerations.

These results are valid only for the stock of cod which visit the Lofoten grounds. We know that spawning cod also occur on other offshore banks in northern Norway. Within the immense population of cod inhabiting the Arcto-Norwegian waters there may exist several more or less independent sub-groups. Certain results of the tagging experiments suggest that this is in fact the case. Until more information is obtained, the validity of the experiments on the Lofoten Banks must be limited to the stock visiting these grounds.

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(2) R o l l e f s e n, G u n n a r. "The Stock of Skrei in 1939". Ann. Biol. **1**, Copenhague, 1943.

Tagging of Escallops (*Pecten maximus*, L.) in Ireland.

By

F. A. Gibson.

On 18. April 1952, 140 escallops were tagged and replanted in known areas of Castletownbere Harbour, Co. Cork. The tagged fish, as can be seen from Table 1, were mostly less than marketable size (11.4 cm. minimum measurement).

The method of tagging involved the use of a small circular disk upon which the legend "Fisheries, Dublin" and a serial number appeared, and to which was attached a short length of silver wire (Figure 2). The left "ear" of the upper shell of each escallop was drilled by an Archimedes drill. The free end of the wire was passed through this hole and the wire twisted around and secured upon itself. The tag in position was freely movable over a half an inch of the shell. Close examination of this method of attachment revealed that it had been completely successful. Up to 10. March 1953, 30 fish (ca. 21 %) have been retaken (see Figure 1).

Although the majority of the escallops at tagging had been well below the minimum marketable size, 16 (53 %) had reached or exceeded this size limit when recaptured. Except in one case, that of the fish bearing tag No. 121, considerable growth was noted. The greatest growth was not always made by those fish which had been longest at liberty (see final column, Table 1).

The average increase in length was 15.6 %, in breadth 15.1 %, and in height 14.0 %. The periods at liberty ranged from 199 to 284 days. The fish bearing tag No. 111 was recaptured in the beds at Mid-Channel (see Figure 1) and it had been recorded as having been planted originally in the beds at Long Point about half a kilometre away. It is now thought that there had been an error in the recording of the planting out of this fish, and that it had in fact been put in the Mid-Channel beds. On the other hand, the fish bearing tag No. 45 was certainly planted at Long Point and was recaptured 1.6 km. away at Step Rock. This fish is the only one so far which showed any sign of a migration, all other fish being taken at the beds where they had been planted originally. In Table 1 the length, breadth, and height of fish at tagging and recapture

Table 1. Recapture of Escallops tagged on 18. April at Castletownbere Harbour.

Tag No.	Length at Tagging	Length at Recapture	Breadth at Tagging	Breadth at Recapture	Height at Tagging	Height at Recapture	Place of Recapture	Date of Recapture	Growth calculations 1st Ring	2nd Ring	3rd Ring	4th Ring	Number of days absent
4	9·6	11·0	10·8	12·5	2·8	3·0	Colt Rock	16/ 1/53	3·1	7·2	9·6		273
24	7·5	9·5	8·6	10·7	2·6	3·3	„	8/ 1/53	3·1	7·0			265
45	9·5	11·1	10·8	12·0	2·9	3·5	Step Rock +	9/12/52	2·4	5·5	8·4		235
70	10·0	11·5	10·8	12·0	2·9	3·1	Ardnakinna	16/ 1/53	2·6	7·4	9·7		273
72	9·5	10·6	10·9	12·1	3·0	3·3	„	„	3·0	6·9	9·2		273
73	8·4	9·7	9·3	10·8	2·7	3·0	„	„	2·7	6·8	8·1		273
75	8·8	9·9	9·9	11·0	2·6	3·0	„	„	2·2	5·7	8·5		273
76	8·4	9·5	9·3	10·6	2·7	3·2	„	5/ 1/53	2·3	5·9	8·2		262
77	7·9	9·8	8·8	10·9	2·5	3·3	„	„	2·6	7·7			262
87	9·2	10·1	10·0	11·9	2·8	3·2	Reendubh	5/12/52	3·0	7·0	8·9		231
90	7·7	10·4	8·8	11·1	2·0	2·9	Foilnaboe	9/12/52	2·7	7·4			235
101	10·1	11·8	11·4	13·2	3·0	3·8	„	„	3·7	8·1	9·9		235
102	7·4	8·7	8·6	10·2	2·4	2·8	Mid-Channel	3/11/52	3·0	7·2			199
104	8·0	9·6	8·9	10·7	2·5	3·1	„	„	3·7	7·6			199
105	8·4	9·9	9·3	11·0	2·6	2·8	„	„	2·0	4·9	8·3		199
106	9·5	10·6	10·6	11·9	2·9	3·3	„	„	2·8	6·6	9·3		199
111	8·5	10·0	9·4	11·4	2·4	2·9	„ (Long Point?)	„	3·9	8·1			199
116	10·0	11·5	10·9	12·8	3·2	3·5	Long Point	26/11/52	3·1	7·4	9·6		222
121	10·8	11·3	12·1	12·9	3·4	3·6	Walter Scott	24/ 1/53	2·3	7·0	9·0	10·4	281
125	9·4	10·8	10·4	12·1	2·6	3·0	„	26/ 1/53	2·9	6·9	9·2		283
128	7·7	9·6	8·9	11·2	2·8	3·0	Walter Scott Rock	13/11/52	3·3	7·4			209
130	9·4	10·4	10·5	11·8	2·8	3·2	„	26/ 1/53	2·5	6·7	9·0		283
131	10·4	11·5	11·9	13·1	3·3	3·4	Privateer Rock	19/11/52	2·8	6·6	9·5		215
132	8·3	9·9	9·0	10·9	2·1	2·6	„	18/12/52	2·8	6·6	8·2		244
133	8·8	10·7	9·9	12·0	3·1	3·5	„	26/11/52	2·4	5·1	8·6		222
134	8·0	9·9	9·1	11·1	2·5	3·1	„	19/11/52	3·1	7·8			215
135	7·6	9·3	8·2	10·4	2·6	3·0	„	13/12/52	3·0	7·2			239
137	8·8	10·6	9·5	11·4	2·6	3·0	Perch Rock	22/11/52	2·7	5·5	8·6		218
138	8·4	10·2	9·7	11·9	2·6	3·2	„	4/12/52	2·2	5·2	8·1		230
140	9·5	10·6	11·0	12·6	2·7	3·1	Privateer Rock	20/11/52	2·7	6·3	9·3		216

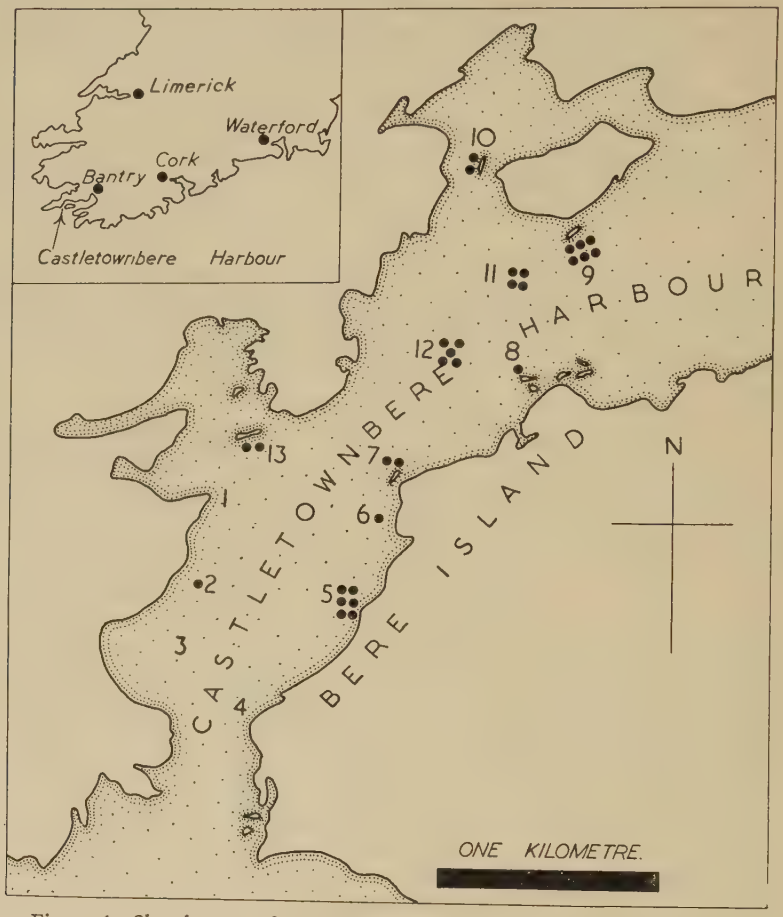

Figure 1. Sketch map of Castletownbere Harbour. Each filled-in circle represents one recapture.

Key:
1. Dunboy Point
2. Step Rock
3. Traneen Rocks
4. Na Glas Point
5. Ardnakinna Battery
6. Reendubh
7. Foilnaboe Rocks
8. Long Point
9. Privateer Rock
10. Perch Rocks
11. Walter Scott Rock
12. Mid-Channel
13. Colt Rock

have been given. The figures relating to the length must be corrected because they refer to the greatest length of each fish. In fact, the upper and flat shell is usually not as long as the lower and round shell, which was always measured to represent total length. The calculated difference between the two shells is about 2 mm. This difference must be taken into consideration when the actual calculated growth measurements in Table 1 are examined. Table 2 shows clearly the relationship of these corrected measurements to the lengths of the fish

Table 2.

Total length at tagging cm.	Corrected lengths	Length of flat shell to ring at recapture	Total length at tagging cm.	Corrected lengths	Length of flat shell to ring at recapture	Total length at tagging cm.	Corrected lengths	Length of flat shell to ring at recapture
9·6	9·4	9·6	7·7	7·5	7·4	7·7	7·5	7·4
7·5	7·3	7·0	10·1	9·9	9·9	9·4	9·2	9·0
9·5	9·3	8·4	7·4	7·2	7·2	10·4	10·2	9·5
10·0	9·8	9·7	8·0	7·8	7·6	8·3	8·1	8·2
9·5	9·3	9·2	8·4	8·2	8·3	8·8	8·6	8·6
8.4	8·2	8·1	9·5	9·3	9·3	7·6	7·4	7·2
8·8	8·6	8·5	8·5	8·3	8·1	8·8	8·6	8·6
8·4	8·2	8·2	10·0	9·8	9·6	8·4	8·2	8·1
7·9	7·7	7·7	10·8	10·6	10·4	9·5	9·3	9·3
9·2	9·0	8·9	9·4	9·2	9·2	8·0	7·8	7·8

at tagging. Within the limits of experimental error the length of the flat shell from the hinge to the outside of the last measurable ring was equal to, or slightly less than, the corrected length of each fish at time of tagging (Table 2). This suggests that the completed ring is laid down during or shortly after April in most cases. It is known that spawning commences in April or May, and occasionally earlier in isolated cases. The ring therefore represents a check in growth due in the main to the demand created by the developing gonads. There should be no lack of feeding during spring, and experiments have shown that the gonads are in an advanced state of development as early as November. There may, therefore, be a limitation of growth between October and May, when all resources are utilized for reproduction, and it seems likely that rapid growth is restricted to the period May to October.

Work is at present being carried out on the immature gonads with a view to establishing the age at which oogenesis and spermatogenesis commence. It seems likely, however, that the first ring is laid down as the result of a rhythm. In other words the ring is laid down in the immature fish as a precursor of rings which are laid down just prior to the spawning season in mature fish. Before this it had been considered that each ring was laid down in winter, and that the first ring was completed at the end of six months, the second of eighteen months, and so on. It now seems likely that the outside of the ring represents the termination point of growth for a period of from six to twelwe months duration. During the present fishing season, October to April, at various times a total of 250 very small escallops have been tagged, but no recaptures have been made to date. These small fish are common in Castletownbere beds at all times of the year.

Table 3. Calculated mean growth rates in centimetres for recaptured escallops with different coloured shells.

	First Ring	Second Ring	Third Ring
Red Shells	2·7	6·3	8·8
Brown Shells	3·1	7·2	9·9
White Shells	3·1	7·9	—

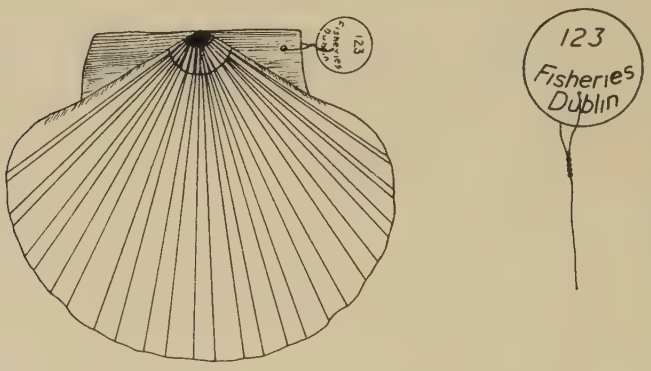

Figure 2. Sketch of upper escallop shell with tag attached, and enlarged view of tag itself.

The measurement of the growth increments in recaptured fish drew attention to the fact that different growth-rates have been recorded for the three predominantly coloured shells found in the area. The growth-rates have been given in Table 3 and it may be seen that the greatest growth was made by white shells and least by red shells while brown shells were intermediate. Only a small number of fish have been so measured and no general conclusions are therefore possible but further experiments in this connexion are in progress.

Résumé.

A successful method of tagging escallops has been evolved giving satisfactory recaptures.

Information obtained from the results so far suggests that the rings on the shell are laid down as pre-spawning growth-checks. The completion of the first growth-check probably occurs at the end of every twelve months.

The growth-rate is probably high from May to October.

Reviews.

G. A. Riley. "Oxygen, Phosphate, and Nitrate in the Atlantic Ocean." Bull. Bingham Oceanogr. Collect., Vol. **13**, Art. 1, pp. 1—126, 33 figs. New Haven, Conn., 1951.

This paper presents a new application of the theory of the distribution of non-conservative properties in the ocean. The distributions of oxygen, phosphate, and nitrate in the Atlantic Ocean are examined critically, and a study is made of the relative importance and order of magnitude of the biological and physical phenomena affecting them. The author first discusses the principal circulatory movements of the Atlantic Ocean, using existing data for temperature, salinity, oxygen, phosphate, and nitrate. It is to be noted that the extensive conclusions of the German workers published in the "Meteor" Reports seem not to have been considered in this respect. The significance of the regional variation of the N-P ratio is also discussed.

Riley continues by outlining the theory of the distribution of non-conservative properties. Considering a point at the centre of a cube of water:—

Rate of local change in concentration of a non-conservative property with time
= Rate of biological assimilation or regeneration
+ Rates of diffusion along the three axes
— Rates of advection along the three axes (changes due to currents).

The theory, in mathematical form, is first applied to a test case. Taking a hypothetical rectangular ocean of similar size and equivalent vertical velocity profile to the Atlantic Ocean, possible values are assigned to the biological rates, and the coefficients of eddy-diffusivity and advection of the phosphate and nitrate. The picture is simplified into two dimensions by assuming that there is a constant horizontal eddy-diffusion, and that the distribution of phosphate and nitrate will not vary latitudinally. The problem is thus reduced to the examination of a north-south vertical section. Specified boundary conditions are laid down, and reasonable concentrations of nitrate and phosphate are assumed for points 1000 km. apart on the section. Assuming that the phosphate regeneration decreases linearly to zero at 800 m., and nitrate to zero at 1400 m., the basic equation is then applied. The resulting model corresponds very roughly with the type of observed distribution. As might be expected from the over-simplified basic assumptions, the agreement of the synthetic model with the observed distributions is not particularly good but after experimentation, the author concludes that it would not be worth while to use a process of trial and error to find assumptions which would make a better fit. Riley therefore abandons a synthetic for an analytical approach which occupies most of the paper.

The observed distributions are now used to derive the physical coefficients and ultimately the biological change rates, in accordance with the basic equation.

By the usual oceanographical methods, a circulation pattern is formulated for the Atlantic Ocean. As the lateral diffusion and advection processes are assumed to follow the isentropic surfaces, this amounts to a calculation of the currents at various σ_t levels between the surface and σ_t 27·8. Below this level a condensed method is used. By averaging the observations from 660 stations in areas whose centres are 1000 km. apart, the mass transport of various σ_t layers was then computed, the usual methods being used, and the fact being ignored that the isentropic surfaces are not level. How much error this introduces remains to be seen.

Following the continuity of the system, inequalities in the transport into, and out of, particular areas are smoothed out by Southwell's relaxation method while appropriate modifications are made in areas bordering the continents. Having produced a picture of relative transport, the author proceeds to convert this into terms of absolute transport by referring to layers of no motion which coincide as nearly as possible with Sverdrup's stipulations of isothermal isohaline surfaces.

Some rather arbitrary assumptions are made, e. g., south-west of Ireland this layer of no motion is taken as about 800 m., where there are considerable water movements[1]). It is possible, however, that over a period of time opposing water movements may cancel out and Riley's assumption of a steady state may be statistically sound.

Several inconsistencies arise in the continuity of the "absolute transport", which are attributed to vertical advection in association with surface phenomena of divergence and convergence. These permit the derivation of approximate vertical advection coefficients. Furthermore the effects of "cabbeling" are postulated as a possible source of error in the case of Mediterranean and Antarctic Intermediate Waters.

To calculate eddy-diffusion coefficients, the salinity distribution is used. Since salinity is not affected by biological changes, the biological rates term may be omitted from the basic equation. Assuming a steady state, the terms still required are advection coefficients — already roughly determined from the mass transport calculations — salinity gradients, and finally the unknown eddy-diffusion coefficients.

If it is assumed for each σ_t layer that the four coefficients of lateral eddy-diffusivity are equal, and also that the two coefficients of vertical eddy-diffusivity are equal, then either can be determined when the other is allowed to fall to zero. A detailed calculation of the equation for the σ_t surface 27·3 is presented, to illustrate the method.

The equation including this assemblage of data is then applied to determine the biological change rates for non-conservative properties, oxygen and phosphate, at each σ_t surface. The limits of error of the method are determined by statistical examination, and the limits of estimate of the biological change rates are tabulated.

Seiwell, who estimated the O_2 utilization in the oxygen-poor layer of the southern North Atlantic, derived an estimated value about 10 times greater than Riley, but Riley's criticism of Seiwell's results may be sound. Wattenberg and Deacon's estimates of the Antarctic Intermediate Current are also 10 times greater than Riley's computations suggest.

[1]) L. H. N. Cooper. Journ. Mar. Biol. Assoc., **30**, p. 494, 1952.

Their arguments, based on an annual variation in the O_2 content of the Antarctic Intermediate Water, appear reasonable, and it is doubtful whether variations due to other causes would have sufficient effect to obliterate so marked an annual cycle as that which occurs in the Antarctic; there are, however, insufficient observations to make these estimates reliable. Riley makes a similar computation for the phosphate regeneration at mid-levels but unfortunately the nitrate data are not sufficient to treat similarly.

Owing to the scarcity of data the Deep and Bottom Waters, are examined by somewhat simplified methods.

The author discusses his findings in relation to the various types of metabolism occurring at different depth ranges in the sea. Reference is made to experimental data of earlier workers on respiration, metabolism, and composition of planktonic organisms.

The general conclusions from the paper suggest that phytoplankton metabolism is particularly important immediately below the euphotic zone, animal metabolism at mid-depths, and below about 1000 m. probably bacterial activity plays the greatest part.

Further evidence is collected to show that the mid-depth maxima and minima in the non-conservative properties result from the complex interaction of biological change rates and turbulence. By altering the vertical gradients of either biological utilization or turbulence, those maxima and minima could be placed at any level below the euphotic zone.

Finally, mathematical models are constructed on the basis of the findings, to test the validity of the original assumptions.

Of the estimated biological rates, that for oxygen change is shown to be the most reliable. This information, with derived values for the O : P and N : P ratios and physical coefficients, is used to build up a picture of the distribution of phosphate and nitrate, similar in most respects to the observed distribution. This reversal of the original process is a severe test of the method, and the agreement between the theoretical model and the observed distribution is remarkably good. This seems surprising when one considers the arbitrary nature of many of the assumptions made and the large number of adjustments to the data necessary throughout the process to preserve the continuity of the system.

After reading this paper, one feels that perhaps the method has been applied before the oceanographical data and our knowledge of the physical processes are sufficient to withstand such a severe test. It emphasizes the need for more precise statement of problems. To quote Lord Kelvin, "When you can measure what you are speaking about and express it in numbers you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."

The author at least makes an attempt to place an order of magnitude upon the physical and biological factors, and this and his other papers on the zooplankton-phytoplankton-nutrient relationship will do much towards placing our knowledge of them on a sounder footing.

L. H. N. Cooper. R. I. Currie.

J. B. Tait. "Hydrography in Relation to Fisheries." (Buckland Lectures for 1938.) pp. XII + 106, frontispiece + 19 figs. Edward Arnold & Co., London, 1952.

Though this excellent little book has not become available until fourteen years after the delivery of the lectures concerned, it could hardly have appeared at a better time. There has recently been a great upsurge of interest in that

division of fisheries research which seeks so to relate fish to their inanimate environment that associations between fish fortunes and the physics and chemistry of the sea adequate to base predictions upon may be hoped for. Very much future work will be necessary, and a lot of it will fall to newcomers to the task. Here is a valuable compendium which will put them *au courant* with what has gone before. Dr. T a i t had no easy story to tell and he was not telling it for specialists; yet so well has he accomplished his task that the reviewer has discerned no obscurities at all. The foot legend to the very useful table (Table 1) which gives the spawning conditions for seventeen kinds of fish is jumbled somewhat, but it can easily be sorted out.

Japanese and (inevitably) much Russian literature apart, we find in this little book a very good account indeed of the major interrelationships between fish and ambient water conditions which have been established up to the present time, more or less. Delivered in 1938 as the lectures were, it was inevitable that several recent notable "correlations" associated with the name of K a l l e find no place in the book. The reviewer is enthusiastically at one with T a i t in his insistence on the supreme (his word) importance of currents as the omnibus factor when considering all that complex of physical and chemical water conditions which make up the total inanimate environment of our food fish.

It would be attractive (as it would be well deserved) to convey here some of the excellent content of these lectures, but the pleasure of making that acquaintance is best left to the many who will undoubtedly read the book.

T a i t is well known of course for the meticulous detail of his work carried out over many years on water movements in the sea areas to which attention has to be paid by those whose task it is to study the fish of the North Sea. Unless the reviewer has got quite a wrong impression, T a i t wants more detail still, and it is there that issue might be joined to some extent. There must ever be some conflict between the claims of detail and "often-ness" in the expensive composite of marine investigations devoted to understanding fish fortunes. The future will, in the reviewer's opinion, see some balance struck between such detailed studies of the environment as can at best relate only to parts of the year (even be they the most critical), and broader, less-penetrating studies which may compensate by "often-ness" and wide regional spread for what they lack in detail.

To assert this assails T a i t' s views less than it pays regard to monetary considerations.

In his stimulating presentations of views on the importance of currents, T a i t naturally lays his own massive drift-bottle work much under contribution. It would be difficult to think of any oceanographical instrument simpler than the common surface drift-bottle, yet what it tells challenges thought a good deal. Dr. T a i t would (we think) contend that no information drawn by him from his drift-bottle experiments is incompatible with what other methods of investigation produce; yet there cannot fail always to be a measure of disquiet from the fact that no simple drift-bottle can be "right" at both ends of a journey commencing in the Atlantic and ending, say, in the Skagerak. If just awash in 26·75 water at the start, it would not be at the surface in 17·50 water at the end. Conversely, if it were ballasted to float just awash in the lighter water, it would sail under wind influence a good deal whilst afloat in the heavier. Moreover, experiment has shown that deep-riding bottles *can* accomplish very different journeys from those performed by ordinary surface floaters. It would seem therefore that there is some need for further thinking in connexion with the simplest humdrum instrument used by

the hydrographer in his fisheries research work. There have already appeared certain presentations of results from drift-bottle experiments wherein stranding frequencies are related to initial and terminal ambient sea water densities, and wherein conjectured bottle tracks are compared with the courses of temperature and salinity isolines. Interesting relationships emerged; the surface drift-bottles showed a tendency to float along lines of equal density, possibly indicating surface flow in the geostrophic sense.

In the domain of fish/water interrelationships within the North Sea, a good deal of importance attaches to the swirls of which Böhnecke originally told us, and to the further delimitation of which Tait has adduced so much evidence from his drift-bottle work. It is therefore of particular interest to have seen from recent work by W. Hansen that the major swirls within the North Sea take form when tidal stream data are worked up in a certain way; but whereas most of them so established exhibit the customary anti-clockwise rotation, that over the S.W. Dogger Bank turns oppositely. This finding of Hansen's as to the opposite rotation of tidal stream eddies could stand in good relationship with the existence of a powerful stream current (of the kind Tait holds to exist) down the middle of the North Sea between about 56°N. and 58°N. latitudes in the Orkneys—Elbe direction.

That we discuss here no points within Tait's accounts of the many fish/water "correlations" with which he deals as established in the past by many different workers in different countries, means merely that we find no reason to join issue over any part of his excellent recital of what had been accomplished up to the time he reported. Since, however, Tait has not been (and could not have been) able to refer to any fish/water correlation of a solid numerical kind upon which reliable predictions could be based, our thoughts naturally turn to the future. The issue seems clear-cut; if no amount of delving into and re-treating the great assemblage of data (both as to fish and water) which has come from the half-century of fisheries research now behind us can be made to reveal some correlation which will serve acceptably for prediction purposes, then we must consider all the more carefully what shape future research ought to take.

To follow Tait where he seems to point would require us to take our coats off and cheerfully accept heavy labour of an exacting kind. His views and the industry which his resulting detailed work calls for may be the right answer; indeed, they may be the only answer. If so, we must wait a goodly time yet before "Fisheries Hydrography" can pay the dividends which the biologists seem (perhaps annoyingly sometimes) to expect. There is at least the chance, however, that fruitful associations of the kind needed may be worked out between fish fortunes and environmental conditions in a more simple way involving less industry and less cost. That is for the future to show; for the present we may well be thankful to possess Tait's valuable account of what the past has accomplished.

J. N. Carruthers.

Johannes Krey. "Die Charakterisierung von Wasserkörpern durch optische Messungen". Arch. f. Hydrobiol., **46**, S. 1—14, 5 Abb. Stuttgart, 1952.

In this paper Krey reports on measurements aimed at characterizing water masses by their transparency. He refers to earlier investigations by Kalle and Joseph, who have worked on the same lines.

The transparency-meter, when standardized, gives values of the true extinction of light in the sea, i.e., the sum of the absorption by suspended and dissolved matter and the scattering by suspended matter. The dissolved

matter is chiefly yellow substance, which is strongly absorbent in the short-wave part of the spectrum.

Krey used the technical means worked out by Joseph and measured the transparency with the aid of an instrument towed from the vessel in motion. The variations of the transparency to red light are ascribed to suspended particles or to turbidity only, as the absorption of red light by yellow substance is practically negligible. The transparency to blue light, on the other hand, is influenced also by the amount of yellow substance. This makes it possible to distinguish between the turbidity and the yellow colouration of the water. These two factors are employed for identifying the different water masses which appear in the water area between the Kiel Bight and the Great Belt. For instance, in January 1945 in the region round Fehmarnbelt it was possible to distinguish 4 different water masses. In some cases the local effect of an outflow of fresh water, which usually contains much yellow substance, was observed.

Yellow substance appears to be a fairly stable product; one can, therefore, expect it to display a relationship with the salinity. The relationship is manifest for the Transition Area, as shown by Joseph, and Krey has given new evidence for it.

Certainly, not only yellow substance but also particles exert a selective action on light in the water. Krey's values for the yellow substance are, therefore, as a rule too high, but this only exceptionally obscures the identification of the water masses. It is clear that optical studies can be developed into an important tool for characterizing water masses and Krey's results have advanced this subject further.

N. Jerlov.

G. R. Hasle. "Phototactic Vertical Migration in Marine Dinoflagellates". Oikos, Vol. **2**, Fasc. 2, pp. 162—175, 7 figs. Copenhagen, 1950.

This paper describes the vertical distribution of four species (*Ceratium tripos, Ceratium fusus, Gonyaulax polyedra,* and *Prorocentrum micans)* in the upper 10 m. of the inner Oslo Fjord, in July. Counts were made, using Utermöhl's sedimentation technique, on water-bottle samples from 0, 1, 2, 5, and 10 m. Temperature measurements and submarine light measurements were also made. The light observations are remarkable in that the transmission of red and green light is much greater than that of blue light. The blue light is absorbed at the rate of one log unit per metre of depth, whereas the red light is absorbed at the rate of one log unit per four metres. Presumably this is related to the distribution of very small particles (the same phenomenon has been reported by Buvig, 1941, and Steemann Nielsen, 1944).

Through two diurnal series, observations were taken at very short time intervals (18 observations in 24 hours). The diurnal variation in numbers at the surface was of the following order:— *Ceratium fusus* ×10, *Ceratium tripos* ×10, *Gonyaulax polyedra* ×5, *Prorocentrum micans* ×2. These diurnal variations were related to the diurnal variation of light intensity. The Ceratia appeared to leave the surface in the daytime, but the numbers of *Gonyaulax* and *Prorocentrum* increased at the surface in daytime. The variation in numbers at the surface of Ceratia is balanced by an inverse variation at 2 m.; this cannot be shown clearly for *Gonyaulax* and *Prorocentrum.*

Observations on vertical migration are subject to certain errors. When observations are confined to the upper layer there is the variance between times of observation due to vertical migration, which can be confused with variance between times due to horizontal drift. This can be overcome by the

use of observations through the whole water column. Southern and Gardiner (1926) have pointed out that if there is no variation in total numbers in a depth series between times of observation in the whole water column, it is likely that the variance due to horizontal drift is not very important. There is a variation of eight times in the total numbers of *Gonyaulax* and a variation of four times in the total numbers of *Prorocentrum*. Variations between depth levels are due to migration or patchiness. If this variation is to be correlated with variation of light intensity, the variance due to patchiness must be taken care of. This has usually been done by taking net hauls of long duration. A large net hauled vertically through 50 or 100 m., or a small net hauled horizontally for 20 minutes or half an hour, will probably catch enough plankton to include a large number of groups or patches. This method is adequate to demonstrate the vertical migration of copepods. For smaller organisms, however, other methods must be used to take care of the variance due to patchiness; a sample of 100 ml. is likely to include only a part of a patch or group. Replication at each depth might do much to reduce this source of variance. In the case of migration of dinoflagellates it is possible that there is an added source of error — that due to the reproduction of the plants, which may well take place at night.

It is clear from this work that *Ceratium fusus* makes a migration from 2 m. to the surface at night. As these organisms are said to move 1 mm. in 4—16 sec., the upward migration would take place in $5\frac{1}{2}$ hours. This sets a limit on the distance through which migration could take place. It is a remarkable fact that such small organisms can be shown to migrate; in this it is comparable to the work of Halme (1938) showing the possible vertical migration of tintinnids. Freshwater workers (Bakjov (1929) on *Ceratium hirundinella* and *Peridinium tabulatum*, Pennak (1944) and Thienemann (1919) on *Ceratium hirundinella*) have shown that dinoflagellates vertically migrate. The question arises whether the migration is not an effect of the diurnal activity of grazing. The diagrams published by Bakjov and Pennak confirm the figure given in this paper in that the increase in numbers at the surface at night is accompanied by a concomitant decrease in numbers at 2—5 m.

D. H. C.

W. V. Kielhorn. "The Biology of the Surface Zone Zooplankton of a Boreo-Arctic Atlantic Ocean Area". Journ. Fish. Res. Bd. Canada, Vol. **9**, No. 5, pp. 223—264, 13 figs. Toronto, 1952.

This paper is one of the first to be published on plankton collected at an Ocean Weather Station in the North Atlantic. It represents a year's work on the zooplankton at Station "B" in the Labrador Sea. Fourteen different United States and Canadian ships occupied the station between February 1950 and March 1951 and it speaks well for the organization of the work that a uniform weekly series of observations was obtained on hydrography, phytoplankton, and zooplankton. The zooplankton was collected in Clarke-Bumpus nets hauled obliquely from 150 metres to the surface at midday and in a 50 cm. tow-net near the surface after dusk.

The author begins with a summary of what is known of the hydrography of the area. This is followed by a list of the species found, with notes on their abundance, the dates on which they occurred, and how their presence at Station "B" fits in with what is already known about their distribution. Observations on transparency and bioluminescence were made during the year and these are discussed. The paper ends with some speculations on seasonal water-mass exchange as deduced from "indicator" species.

The most important aspect of this paper is that it gives for the first time a continuous record of the zooplankton at an oceanic station throughout a year, including the winter, for which there have previously been so few observations. Similar work is being done at several other stations from American, Norwegian, Netherlands, and British Weather Ships and together the results should give a much clearer picture of the plankton of the North Atlantic.

One of the old ideas that will have to be modified as a result of the Weather Ship work is that of the barrenness of the open oceans. Kielhorn comments on the abundance of copepods at Station "B", particularly of *Calanus finmarchicus* which dominates the plankton there. Evidence is accumulating that some oceanic areas of the North Atlantic are as rich as many of the coastal areas and banks, and this may prove of major importance in the development of fisheries.

As the work at Station "B" is being continued there should be further reports. Only by observations over a number of years can one find what is the normal pattern. The author assumes that 1950 was a "normal" year, but several hydrographic reports suggest that it was an odd year in the North Atlantic when compared with previous years. The concept of what is "normal" is important for a discussion of "indicator" organisms. In winter in the Labrador Sea were found single specimens of several species which the author takes to show an influx of boreal-subtropical water from the south-east. It seems equally likely that they came with the Irminger component of the West Greenland Current. For these species to be good indicators more should be known of their oceanic distribution and more than one specimen should be caught.

Another concept that may be revised as a result of Ocean Weather Ship studies is that of "oceanic" and "coastal" species. For instance, Kielhorn found several specimens of the "coastal" cladoceran *Evadne nordmanni* at Station "B" in summer and cannot explain their presence. Unpublished records from Stations "I" and "J" in the eastern Atlantic show that this species occurred regularly at both stations from May to August in 1949 and 1950, sometimes in considerable numbers — and usually it was found at the same time as doliolids — so it would seem to be not a truly coastal species.

This and other problems should be solved as the work proceeds, and Kielhorn's paper is a good beginning.

John Corlett.

S. M. Marshall and **A. P. Orr.** "On the biology of *Calanus finmarchicus*. VII. Factors affecting egg production". Journ. Mar. Biol. Assoc. U.K., N.S., **30**, 3, pp. 527—547, 1 plate + 5 figs. Cambridge, 1952.

Before the experiments described in this paper very little was known about the egg-laying in *Calanus finmarchicus*, and it is very interesting to get factual information on the matter.

The authors first describe the ripening and laying of eggs in *Calanus finmarchicus*. Females, collected by means of coarse tow-nets, were kept singly in small dishes in about 20 ml. of sea water which had been ultrafiltered, and in the several experiments varying quantities of diatoms and flagellates were added. Both the maximal number of eggs laid, nearly 600, and the duration of the spawning period, up to 74 days, were much above the figures hitherto assumed. A single fertilization was sufficient for the whole period of egg-laying.

The eggs were laid in batches of from 20 to 60 eggs, and the production

often took place in a series of bursts lasting for about a week. The bursts tended to occur at intervals of two weeks, and were possibly related to the phases of the moon. After the 40th day the number of eggs produced per day decreased considerably. In March *Calanus* laid eggs mainly in the early morning, but in May the process continued over the whole 24 hours of the day.

Eggs of *Calanus helgolandicus* were generally larger than those of *C. finmarchicus,* but intermediate sizes also occurred.

The authors were able to show that both the rate of production and the number of eggs spawned were entirely dependent on food. When starved, *Calanus* soon ceased to produce eggs, but egg-laying was very soon resumed when the starved females were fed again, and their total egg production was not less than in females fed continuously. Immature females, when offered a plentiful supply of food, may start producing eggs after 4 or 5 days.

An attempt was made to measure the relation between the increase in food and increase in egg production. It was found that with 7 to 8 cells of *Chlamydomonas* per mm.^{3}, production was nearly the same as in starved individuals, but increased very rapidly up to 40 cells per mm.^{3}; higher concentrations did not increase the production. The lowest figures which led to increased egg production were less than those occurring in a normal spring diatom increase in the area investigated, although the minimum concentration given (7—8 cells/mm.^{3} = 7000—8000 cells per ml.) was, according to Nicholl's figures (1933 a[1]), p. 93), as high as occurs during a normal spring increase of diatoms.

Not only the amount of food offered, but also the kind, was of importance. Diatoms proved successful, but some others, e. g., *Hemiselmis rufescens* and *Chlorella stigmatophora,* did not result in egg production. A rise of the pH value or addition of cell-free filtrate from a *Chlamydomonas* culture had no effect on the egg-laying.

It is assumed that successive broods of *Calanus,* and probably also of some of the smaller copepods, depend on outbursts of diatoms. The authors also suggest that the egg production of ripe *Calanus* can be used to test the nutritive value of different food organisms.

An interesting point was that when starved, *Calanus* soon ceased to produce eggs, although the store of fat was not affected, being retained right to the end of the experiment.

The authors are to be congratulated on this fine piece of work. The results will be of great importance to plankton workers tackling the problems of the rate and amount of production of copepods in the different areas. It is essential to know that the production of eggs by individual females may be extended for such a long period, and that *Calanus* is not lost if diatoms are not immediately present, but can retain their eggs till better times. How *Calanus* populations may become distributed over wide areas, and how a small stock of adults may, when there is good supply of food, give rise to the enormous populations which are found in many northern waters, can also be understood.

Too many of the conclusions reached in quantitative plankton work are based merely on assumptions and calculations. Experimental work is needed to give factual information, and it is hoped that the authors will continue their work.

Kr. Fred. Wiborg.

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[1]) Nicholls, A. G., 1933. "On the biology of *Calanus finmarchicus* I. Reproduction and seasonal distribution in the Clyde sea-area during 1932." Journ. Mar. Biol. Assoc., **19**, pp. 83—110.

Margaret E. Brown. "The Growth of Brown Trout (*Salmo trutta* Linn.) IV. The effect of food and temperature on the survival and growth of fry". Journ. Exper. Biol., Vol. **28**, No. 4, pp. 473—491, 9 figs. Cambridge, 1951.

Considerable controversy has arisen in the discussion on the factors that govern the formation of annuli and circuli on fish scales. As an intermediate step towards a final solution of the problem, Miss Brown has studied the effect of certain factors on mortality and growth; the effect of these on scales will be examined later.

Trout fry were grown in aquarium tanks. The environmental conditions in the tanks were under close control. The cooling system is carefully described. The factors examined were temperature (10·5° and 12·5°C.), type of food (fresh minced liver, live *Tubifex*, and dried shrimp meal) and frequency of feeding (1, 3, 7, and 13 times a week and later 2, 4, 7, and 13 times a week).

The effect of temperature on the vital processes of the fry is evident from many examples. Growth was slower at 10·5° than at 12·5°, provided the fry were not starved (fed at least once daily). The mortality peaks were delayed at the lower temperature. Especially interesting is the delay of the onset of the "*Tubifex*-mortality" (*vide infra*).

Once again liver turned out to be superior to other types of food. With live *Tubifex* food the fry grew very well up to a certain size but then a heavy mortality started, the fry showing dilation of cutaneous blood vessels and bleeding from the fins. Either, the author concludes, *Tubifex* lacks some substance essential to the fry, or contains some substance which accumulates in the fry and acts as a poison. The insufficiency of shrimp meal — unlike the *Tubifex* food — was apparent almost from the beginning of the experiment, as the fry very early showed bad condition as well as poor growth and survival. It is interesting to note that fry fed with live plankton Crustacea (not used in this particular experiment) remained healthy and grew faster than any of the "experimental" fry. May that not be a pointer towards the more precise composition of the vitamins at work here?

Investigations on the importance of feeding frequency revealed that mortality was high among fry fed once a week, although they were allowed to eat as much as they wanted. The maintenance requirements of trout fry in the experiment were satisfied by feeding somewhat less frequently than twice a week, as those fed twice a week showed slow growth. Fry fed with liver showed better growth the more often they were fed. This was less evident when the fry were fed with the deficient types of food; for instance, fry fed with *Tubifex* died at a certain size, as stated above, and they died earlier when fed more frequently, but a better growth was not recorded under any of the conditions of the experiment.

The behaviour of the fry varied with different feeding frequencies. The starved fry showed greater enthusiasm for the food and consumed so much that they bulged. It is estimated that the food consumed by fry in the different groups was roughly 4 : 3 : 2 : 1 although the feeding frequency was 13 : 7 : 3 : 1 (later 13 : 7 : 4 : 2). This "appetite" factor seems to be very important when food is discontinuously provided, but how does it function when food is continuously available? Another question, If Myer's results, quoted by Miss Brown, are correct, the fry do not hunt for their food until some time after they have begun to feed. Might not the appetite factor be nullified when food is scarce? Again, in the experiments the appetite factor did not succeed in counter-balancing the frequency of feeding, although it tended to do so, since those fed more often normally grew better. But when

the fry were starved, neither the higher temperature nor the better type of food (liver) could induce a significantly better growth. Perhaps this was because growth in all these cases was so small that differences were difficult to detect although they existed. A complementary explanation is, however, that the appetite factor was engaged in a maintenance mechanism and always acted to secure sufficient food for maintenance.

The effect of "size hierarchies" was also apparent in the present experiment as it was in earlier work by the same author. Obviously the facts revealed in Miss B r o w n' s work form a good basis for a differential growth in fish. A uniform growth-rate, far from being characteristic of a species, can no longer be accepted as characteristic of fry belonging to the same year-class, species, and lake, and this has far-reaching consequences.

T. Lindström.

R. H. Lowe. "The Influence of Light and Other Factors on the Seaward Migration of the Silver Eel (*Anguilla anguilla* L.)". Journ. Anim. Ecol., **21**, (2), pp. 275—309, 13 figs. Cambridge, 1952.

Because the import of eels from the Continent to Britain completely stopped during the war, it was decided to try to raise the yield of this fishery in Britain itself. Accordingly during the period 1941 to 1944 the author studied in the English Lake District the seaward migration of silver eels, and subsequently produced this paper, which can be roughly divided into 4 main parts covering field observations, light experiments, some laboratory experiments, and the discussion.

The field observations provided some nice results. The chief of these is that silver eels in the area concerned seem to be influenced by the water-flow; floods often caused a strong migration. According to the author the migration season — between late summer and early winter — is started by a flood. Moonless periods are also of advantage. Silver eels often migrated on the same nights at widely separated places and seemed to migrate earlier the further upstream they lived in a river. However, not all the data support this last idea.

Light experiments showed that light may be instrumental in stopping the migration for at least half an hour. It was also shown that light may deflect the majority of migrating eels to the darker side of the river.

The laboratory experiments provided some information about swimming capacity and also showed that light depresses the activity of silver eels. The author's statement that eels kept in tanks were highly active on nights when migration occurred in the field is particularly noteworthy.

In the discussion the author tries to describe and to explain the behaviour of migrating silver eels. With regard to this, the author seems to hold ideas about animal behaviour which do not completely agree with the principles of animal ethology. Perhaps the author is not conversant with the ethological literature; at any rate not a single paper on this subject is mentioned. Moreover, her acquaintance with the studies of other eel investigators appears to be rather limited; for instance, the beautiful and extensive papers of M e y e r and N o l t e dealing with the effects of the moon and the weather upon silver eel migration are not mentioned (*Zeitschrift für Fischerei,* 1938).

Perhaps for this reason the author gives the impression of having a rather narrow outlook on the occurrence and behaviour of silver eels in different environments. A conclusion to the effect that floods seem to provide the initial migratory stimulus to *all* silver eels is incomprehensible to anybody who is aware of the silver eel catch of 1·03 million kilogrammes in 1952 in Lake IJssel, which is stagnant.

C. L. D.

H. A. Cole. "The American Slipper Limpet (*Crepidula fornicata* L.) on Cornish Oyster Beds". Min. Agric. and Fish., Fish. Invest., Ser. II, Vol. **17**, No. 7, 13 pp., frontispiece + 1 fig. London, 1952.

Since its accidental introduction to Essex waters in the 'eighties, the American slipper limpet has extended its range considerably and became a nuisance in several oyster districts. It was not until a few years ago, however, that this notorious oyster pest made its appearance on the Cornish oyster beds, peculiarly enough without settling in the intervening Plymouth area. After presenting the data relating to the finding of *Crepidula* in Cornish waters, Cole discusses the various means it uses to reach new grounds, and the apparent difficulties the slipper limpet encounters in extending its range. I agree with Cole that it is highly improbable that *Crepidula* reached the Cornish waters from the east as pelagic larvae, not so much because "there is no evidence at all that *Crepidula* larvae can survive and be carried this distance", for the larvae can thrive in swift-flowing water, but primarily because the prevailing currents protect the Cornish coast from such an unwelcome invasion, the residual current in the English Channel being towards the Straits of Dover, and the nearest *Crepidula* beds being found off Dorset and Devon. For the same reason wreckage has not been a probable disseminator here. French oysters for relaying cannot have carried the slipper limpet to Cornish waters either. Most probably *Crepidula* came in attached to a ship's hull. It is true that only occasionally the limpets are found on a ship's plating in numbers worth mentioning, and that single adult limpets that have been dislodged will rarely survive, but in the war years ships often sojourned for prolonged periods in *Crepidula*-infested waters, and often their hulls were not cleaned before they were moved to other ports or to shipbreaking yards. Convincing evidence is adduced that entire chains of *Crepidula* (capable of reproduction) can be found on the bottoms of ships under such conditions, and Cole believes that such colonies, dropped or scraped off, can start a new focus of infection. This may be true, but I feel that Cole underestimates the alternate possibility that *Crepidula* attached to a ship's bottom infest new areas by producing larvae during the often prolonged sojourn of the ship in other waters.

It seems impossible to eradicate *Crepidula* from Cornish waters completely, and as some dense beds of shell offer a favourable substratum there is every reason to expect that *Crepidula* will increase in numbers and will eventually overrun several Cornish oyster beds. Methods of control are only practicable on those beds which are in private hands. As from many other points of view free fishery on the scanty remains of natural oyster beds is anachronistic, Cole advocates passing the beds under consideration into the hands of oyster farmers. Proper leasing terms, enforcing regular cleaning of the grounds, will not only prevent a disastrous spreading of slipper limpets, but may serve at the same time to increase the production of native oysters.

P. Korringa.

E. W. Knight-Jones. "Reproduction of Oysters in the Rivers Crouch and Roach, Essex, during 1947, 1948, and 1949". Min. Agric. and Fish., Fish. Invest., Ser. II, Vol. **18**, No. 2, 48 pp., frontispiece + 15 figs. London, 1952.

Among the investigations into the conditions for the revival of the Essex oyster industry studies on the oyster's reproduction in the rivers Crouch and Roach rank first. Of course, the fecundity of the oyster gives the best hope of revival. This is the more so because the losses during the planktonic stage due

to the sweeping of larvae out to the sea are very limited, since the tides in these rivers perform an almost ideal piston-like movement. Moreover, both temperatures and salinities prevailing in these waters during the summer months greatly favour the development of oyster larvae. Detailed information is given on hydrographical and biological conditions in the summer seasons of the years 1947, 1948, and 1949. Knight-Jones draws some interesting conclusions from his quantitative data on production and development of larvae. His sampling method (100 l. of water pumped from a depth of 2 m.) appeared to be adequate. That the size of the breeding stock determines the number of larvae produced follows clearly from differences observed between the rivers Crouch and Roach. There appeared to be a marked tendency for spawning to be concentrated on spring tides. Knight-Jones advances the interesting view that this spawning rhythm, and those in many other marine animals, may have the possible advantage that the larvae spend their first few days of independent life, during the critical change from lecitotrophic to planktotrophic habits, in conditions of minimum turbulence and turbidity (neap tides). Size, growth, and survival-rate of the larvae appeared to be markedly similar to those in the Oosterschelde. Low water-temperatures tend to slow up larval development, allowing an increased toll to be taken by vast populations of filter-feeders (*Crepidula, Elminius,* Ascidia, etc.) and by pelagic enemies. Temperature is, however, not the only factor affecting the duration of the planktonic phase. Most probably the food factor is often the bottle-neck for larval development in the Essex rivers. The usual concentration of nanoplanktonic flagellates of less than 5 per $mm.^3$ seems to be somewhat too sparse for good growth of oyster larvae. Periods of improving weather conditions usually lead to a marked increase in the number of flagellates, and this in its turn encourages a better development of oyster larvae. Knight-Jones explains why constantly high temperatures lead to poorer results in terms of nanoplankton development and increased grazing by ciliates, rotifers, and similar rapidly multiplying forms.

The time at which spatfall peaks occurred coincided very neatly with the appearance of peak numbers of eyed larvae in the plankton samples, which proves again that Knight-Jones's methods of sampling are adequate. Spatfall proved to be about twice as heavy on shells taken from well stocked beds as on shells from barren grounds, which confirms earlier findings, and corresponds with our experience in the Oosterschelde. Knight-Jones explains this in terms of gregariousness in setting. But when he found that the reverse was the case with artificial collectors, kept off the bottom, he explains that the excellent setting on surfaces exposed on barren grounds should be attributed to the lack of other cultch there. Fouled shells appeared to be much less efficient as collectors than bleached shells.

Elminius modestus, steadily increasing in numbers, appeared to be a serious pest, not only because it devours many oyster larvae, but especially because it crowds surfaces destined for oyster spat. Only when oyster larvae have settled more than a week previously may they grow over the surrounding young barnacles, but in this process they become misshapen. Spat collection with artificial collectors on an experimental scale was not yet remunerative here, mainly because of competition by *Elminius* and because of the heavy losses the spat suffers shortly after settling.

Knight-Jones discusses the possibility of promoting the growth of oyster larvae artificially by addition of nutrient salts to the water, though he is aware that this should be done very cautiously. He does not see, however, how one could prevent competitors and pests like *Elminius* and *Crepidula*

from benefiting greatly from such fertilization. I wonder whether dredging away of most of the *Crepidula* would not result in better general conditions of nourishment in the Essex rivers.

P. Korringa.

D. B. Quayle. "Structure and Biology of the Larva and Spat of *Venerupis pullastra* (Montagu)". Trans. Roy. Soc. Edinburgh, Vol. **62**, Part 1, pp. 255—97, 20 figs. Edinburgh, 1952.

The communication consists of two distinct parts, part A dealing with the anatomy, and part B with the biology of the larval and spat stages of the lamellibranch.

A. The fully grown larvae are 250—260 μ long. The hinge has 15 small teeth on a solid bridge. It would be of interest to know if the number of teeth on this type of hinge is constant for a species.

The various organs of the fully grown larva are described. The illustrations are numerous and clear; the key to the reference letters is placed at the very end of the paper. The velum is the organ of feeding. The gills may function as respiratory organs, and it is suggested that the muscular lobes of the mantle control the respiratory current. Pelagic larvae which are resting on the ventral shell edges can move by the ciliary activity of the foot.

The major changes that occur during metamorphosis are also described in detail. There are, in particular, three important changes. (1) The velum is lost. The bulk of the velum is rapidly sloughed off soon after settling, but the apical plate forms the beginning of the upper palps. The gills now become the food-collecting organs, although the food groove does not appear until the larva is above 1 mm. long. (2) The byssal gland becomes active. (3) The dissoconch begins to appear immediately after settling.

B. The numbers of larvae obtained in a regular series of pump samples in 1947 suggest a first main spawning about 10. June and a later main spawning about 10. August. The spawning season in 1946 lasted from mid-May to mid-July, and in 1947 from mid-June to end of August. The lag in 1947 may have been due to retardation of gonad development during the preceding cold winter.

Larvae were found over a considerable depth, 0—30 m. for *V. pullastra*, and other lamellibranch larvae were found at 40 m.

Dr. Quayle interprets the results obtained in three sets of samples as showing a "strong possibility" that a diurnal migration of larvae occurred. It is undeniable that this is a possible interpretation. The reviewer considers, however, that an alternative interpretation is possible in terms of state of tide, the semi-diurnal tides, which differ appreciably in range, being also distinguished. The water at a single station is not static but is continually changing with the tidal streams so that plankton samples in a series taken at one station may well be from different bodies of water. This would not matter if the distribution of an organism was uniform over a large area, but it is probable that larvae of *V. pullastra* are spawned in parcels, as it were, in a few inter-tidal areas and dispersed only slowly. Correlation of numbers of larvae obtained with state of tide would follow if nearly the same body of water was sampled at nearly the same state of tide on successive occasions.

This point applies also to the regular series of pump samples (Fig. 15) where there may be a correlation with the spring-neap cycle. The two peak numbers of the first group and the three peaks of the second are separated by approximately 14 days. In this case the estimate of 30 days for the pelagic life of the larva is not very satisfactory.

The settling of spat upon ground-glass and Tufnol plates held suspended

at various angles was investigated. Spat were found only on the upper surfaces. There was a correlation between number of spat and plate angle, the greatest number occurring on plates nearest to the horizontal. However, the number settling per square inch of horizontally projected area increased with angle up to the vertical, and this suggests that downward vertical movement of the larvae is not an important factor in attachment. It is possible that detritus is an essential factor in settlement.

Finally, a most interesting account of mortality, following a large spatfall in Balloch Bay in 1946, is given. By June 1947, mortality had reached nearly 100 %. The main cause is believed to be the unsuitability of the ground for older spat; the surface layers of sand shift considerably, so that the spat become smothered. Other contributory factors are discussed.

Dr. Quayle expresses the belief that spat survival is largely a matter of chance. Any choice by larvae of settling ground satisfies, in the main, the immediate needs of the spat, which may differ from the needs of the adult. Examination of various surfaces reveals the spat of many species in areas totally unlike the adult habitat. The reviewer would point to the settling of *V. pullastra* on suspended plates as a good example of this.

C. B. Rees.

Current Bibliography.

Prepared by the Editor with the Assistance of Mr. A. R. Margetts.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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A Guide to Fish Marks

used by Members of the

International Council for the Exploration of the Sea,

and by some non-participant countries.

Second Edition.

Instructions for using the Guide.

In the present revision the lay-out used in the first Guide, published in Vol. VII, No. 1, of this Journal, has been retained, and similar instructions for using the Guide apply. An alphabetical list of the distinguishing letters (**E**, **D**, etc.) engraved on the fish marks is given on p. 242. The nationality of the institution issuing the mark and a reference to the appropriate page of the pamphlet is shown against each letter. Pages 246—289 comprise the body of the Guide; they are arranged according to nationality. Similar marks used by different institutions are described separately. In order to identify the source of a mark, the distinguishing letters should first be sought on p. 242, where a reference to the appropriate section of the pamphlet will be found. There an illustration of the mark is given with all necessary details on the same page. Within the countries the marks have been arranged according to (a) general nature — disk, hook, tag; (b) material — metal, celluloid, plastic, and (c) kind of fish — shellfish.

For convenience, the names and addresses of at least one institution which deals with marked fish in each country have been listed on p. 245, and the varieties of fish marked, with references to the appropriate pages on which they are mentioned, are thus listed, on p. 243. The names and addresses of firms manufacturing marks or components are given on p. 244.

List of Distinguishing Letters to be found on fish marks, with nationality of marking institution and page reference.

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A	USA	283
B	USA	283
	England	259
CB	USA	288, 89
D	Denmark	254
	England	258
	Germany	261, 62
Da	Denmark	252, 53, 54
DaF	Denmark	252
DaG	Denmark	252
DA	Denmark	252, 54, 55
D. A.	Denmark	255
DAG	Denmark	253
DAN	Denmark	252
DANA	Denmark	253
DFV	Germany	262
DH	Germany	261
D.Ha	Germany	261
DPQ	Canada	249
E	England	257, 58
EW[1] EX	England	257
FRB	Canada	247, 48
G	Denmark	252
I	Iceland	264
ISL	Iceland	264
Isl-V	Iceland	264
N	Norway	268, 69, 70, 71
PE	England	259
PH	England	256
PORT	Portugal (reserved — cod)	
R. F.	France	260
S	Sweden	278
SA	Sweden	278
Sb	Sweden	278
Sc	England	258
	Scotland	272, 75
SC	Scotland	272
S. C.	Scotland	273, 74
SF	Sweden	278
Sk, Sm	Sweden	277
Sv	Sweden	276, 77, 78
SV	Sweden	277
Sw	Sweden	277
US	USA	283
W	England	258

[1]) or other second letter.

Lea Hydrostatic tag:—

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Denmark	254
Iceland	265
Ireland	266
Norway	270
Scotland	275
Sweden	276

No letter given, but address:—

Canada,	disk	247, 48, 51
	tag	248, 49, 50
Ireland,	tag	266
Scotland,	boat-shaped pieces	273
	tag	273
USA,	disk	279, 80, 81, 82, 86
	tag	284, 86, 87
	hook	284

Number only:—

Canada,	tag	248, 50
England,	disk	259
Germany,	disk and clip	263
Iceland,	tag	265
Netherlands,	tag	267
Norway,	tag	271
USA,	tag	285, 87

For letters not mentioned here, see also:

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Iceland	264
USA	283

Species of Fish Marked, with references to the appropriate pages.

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Amber Jack (*Seriola dumerlii*) 285
Blackback Flounder
(*Pseudopleuronectes americanus*) 279
Blue Crab (*Callinectes sapidus*) 288, 89
Carp (*Cyprinus carpio*) 267
Char (*Salmo alpinus*) 253, 54, 265
Cod (*Gadus callarias*) 247, 49, 252, 53, 54, 57, 260, 64, 68, 69, 270, 76
Crab (*Cancer pagurus*) 275
Dab (*Limanda limanda*) 261, 272
Eel (*Anguilla vulgaris*) 249, 250, 262, 277
Escallop (*Pecten maximus*) 259, 266, 279, 286
Flatfish (Pleuronectidae) 252, 261, 63
Flounder (*Platichthys flesus*) 252, 261, 276
Fluke (*Paralichthys dentatus*) 279
Freshwater Fish, Various 263
Greenland Shark (*Somniosus microcephalus*) 252
Grey Mullet (*Mugil cephalus*) 282, 85
Haddock (*Gadus aeglefinus*) 247, 273, 74, 75, 79
Hake (*Merluccius merluccius*) 260
Halibut (*Hippoglossus hippoglossus*) 248, 252, 270, 72
Harp Seal (*Phoca groenlandica*) 251
Herring (*Clupea harengus*) 246, 253, 54, 55, 57, 260, 64, 270, 71, 72, 73, 75, 76
Lemon Sole (*Microstomus kitt*) 272
Lobster (*Homarus vulgaris*) 250, 275
„ (*Homarus americanus*) 286, 87
Mackerel (*Scomber scombrus*) 269, 270, 71
Pilchard (*Clupea pilchardus*) 260
Plaice (*Pleuronectes platessa*) 252, 54, 57, 260, 61, 64, 68, 272, 76
Red Mullet (*Mullus surmuletus*) 260
Sailfish (*Istiophorus americanus*) 279, 285
Salmon (*Salmo salar*) 248, 49, 253, 54, 58, 264, 65, 66, 270, 75, 77, 78
Sea-Trout (*Salmo trutta*) 258, 266, 270, 74, 77, 78
Shad (*Alosa sapidissima*) 249, 250, 281, 82, 84
Sharks (Pleurotremata) 283
Skates (Hypotremata) 256, 272, 280
Sole (*Solea solea*) 261
Spiny Lobster (*Panulirus argus*) 287
Striped Bass (*Roccus lineatus*) 249, 250
Sturgeon (*Acipenser sturio*) 249
Trout (*Salmo fario*) 248, 252, 53, 54, 55, 262, 65, 66
Tunny (Scombridae) 260, 285
„ (*Thunnus thynnus*) 260, 283, 84
„ (*Germo alalunga*) 260
Turbot (*Scophthalmus maximus*) 261, 276
White Marlin (*Makaira albida*) 283, 85
White Perch (*Morone americana*) 281
Whiting (*Gadus merlangus*) 260
Winter Flounder
(*Pseudopleuronectes americanus*) 247, 280
Yellowtail Flounder (*Limanda ferruginea*) . 279

Manufacturers of Marks.

Denmark

Petersen Disks

Messrs. Heimbürger, Købmagergade 63, Copenhagen.

England

"Silktex" Herring Tags

Malcolm Campbell (Plastics) Ltd., 5, Great James Street, London, W. C. 1.

Engraved Yellow Ivorine Disks, $^1/_2$" dia. × $^1/_{16}$" thick.

Black Blank Ivorine Disks, $^1/_2$" dia. × $^1/_{16}$" thick.

Reliance (Nameplates) Ltd., Richmond Bridge Works, Twickenham, Middlesex.

Black "Tufnol" Disks (engraved or blank)

Tufnol Ltd., Perry Bar, Birmingham 22 B, and Kent House, 21, Spring Gardens, Manchester, 2.

Cellulose Nitrate Marks

Messrs. Charles Neal & Son, 378, High Road, East Finchley, London, N. 2.

Monel Metal Numbered Disks (circular, $^1/_2$" dia.; oval, $^3/_4$" × $^1/_2$")

Frank Baker & Sons Ltd., 27—29, St. Paul's Square, Birmingham.

Silver Wire, 0·018" and 0·025" dia.

Johnson, Matthey, & Co., Ltd., 73—83, Hatton Garden, London, E. C. 1.

Germany

Rugela Marke

Firma R. Jung, Heidelberg (siehe W. Koch, Arbeit über Fischmarkierungen in *Ztschr. f. Fischerei,* 1937, Bd. 35).

Fima Zange

Firma Otto Lampson, Karlsruhe i. B., Waldstrasse.

Norway

Disk Tags

A/S Protector, Chr. Michelsensgt. 11, Bergen.

Lea Hydrostatic Tag

Mr. Einar Lea, Fiskerikonsulent, Biolog. Lab., Fredriksgt. 3, Oslo.

Internal Steel Tag

Bergen Nautik, Strandgt. 18, Bergen.

Scotland

Plaice Tags (Ebonite Disk Type)

Messrs. Nicol Smith Co. 37, Belmont Street, Aberdeen.

Crab and Lobster Tags (Oval Copper Disks)

Messrs. Shirras Laing & Co., Ltd., Schoolhill, Aberdeen;
Messrs. H. & J. Bryce, 40, Upperkirkgate, Aberdeen.

As they are liable to frequent variation, prices are not noted.
Current prices and delivery times may be obtained from the firms direct.

The Principal Offices for receiving particulars of marked fish, including foreign-marked; at least one address is given for each country. (For alternative addresses within each country, see pages dealing with individual marks.)

Belgium	Directeur, Institut d'Etudes Maritimes, Ostende.
Canada	Atlantic Biological Station, St. Andrews, N.B. Newfoundland Fisheries Research Station, St. John's, Newfoundland.
Denmark	Danmarks Fiskeri- og Havundersøgelser, Charlottenlund Slot, Charlottenlund.
England	The Director, Fisheries Laboratory, Lowestoft. The Director, The Laboratory, Citadel Hill, Plymouth.
France	Institut Scientifique et Technique des Pêches Maritimes, 59, avenue Raymond-Poincaré, Paris (16e).
Germany	Biologische Anstalt, List, Sylt. Bundesanstalt für Fischerei, Institut für Küsten- und Binnenfischerei, Hamburg 36, Neuerwall 70-74.
Iceland	Fiskideild, Borgartún, Reykjavík.
Ireland	Department of Agriculture, Fisheries Branch, Dublin.
Netherlands	Rijksinstituut voor Visserij-onderzoek, Oost Indisch Huis, Amsterdam.
Norway	Fiskeridirektoratets Havforskningsinstitutt, Postboks 226, Bergen.
Scotland	The Director, Marine Laboratory, Scottish Home Department, Wood Street, Torry, Aberdeen.
Sweden	Kungl. Fiskeristyrelsen, Göteborg. Havsfiskelaboratoriet, Lysekil.
United States of America	U. S. Fish and Wildlife Service, Washington, D. C. State Board of Fish and Game, Hartford, Connecticut. Marine Laboratory, University of Miami, Coral Gables, Fla.

BELGIUM

Marking Institution	Institut d'Etudes Maritimes, Ostend.
Type	Lea Hydrostatic tag.
Figure	For description and figure see pp. 265, 270, 276.
Use	**Herring.**
Scale of Reward	For the fish and mark, with date and place of recapture ..... 70 Fr. b. For the mark alone, with the same information .. .. 35 Fr. b. For the mark alone, without information .... 17.5 Fr. b.
Reception Office	Director, Institut d'Etudes Maritimes, Ostend. Director, Service de la Pêche Maritime, Ostend. Any fishery laboratory in the countries participating in I. C. E. S.

CANADA

Marking Institution Fisheries Research Board of Canada.

Type Bright red celluloid disk with an aluminium backing carrying a stud which fits into the hole in the disk.

Figure

Use **Cod** and **Haddock.**
Applied by special pliers through a hole punched in the opercular bone.

Scale of Reward For tags and information ..... 1.00 dollar.

Reception Office Newfoundland Fisheries Research Station, St. John's, Newfoundland.

Marking Institution Fisheries Research Board of Canada.

Type Red and white celluloid disks attached by a nickel pin; stamped "Fisheries Research Board, St. Andrews, N. B. Return both disks. Reward" and "**F. R. B.** — (Number)".

Figure

Use **Winter Flounder** (*Pseudopleuronectes americanus*).
Tags attached through the flesh at the nape of the neck; the white disk is placed against the dark skin and the red disk against the white skin of the fish.

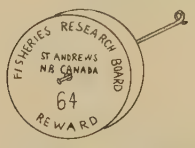
Scale of Reward For tag and information ..... 50 cents

Reception Office Atlantic Biological Station, St. Andrews, New Brunswick.

CANADA

Marking Institution Fisheries Research Board of Canada.
Type Two white celluloid disks attached by a nickel pin. Stamped "Fisheries Research Board, St. Andrews, N. B. Canada. Reward — (Number)" and "F. R. B. — (Number)".

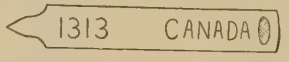
Figure



Use **Atlantic Salmon.**
Attached at anterior base of dorsal fin.
Scale of Reward For tag and information ..... 1.00 dollar
Reception Office Atlantic Biological Station, St. Andrews, New Brunswick.

Marking Institution Fisheries Research Board of Canada.
Type Monel metal strap tags of two sizes (69 and 57 mm.); stamped "Canada" and a number.

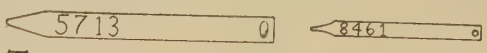
Figure



Use **Halibut.**
Tag is bent and clenched on operculum.
Scale of Reward For tag and information ..... 1.00 dollar
Reception Office Atlantic Biological Station, St. Andrews, New Brunswick.

Marking Institution Fisheries Research Board of Canada.
Type Monel metal strap tags.
(1) Large (No. 2) tag.
(2) Small fingerling tag.
Both stamped with a number only.

Figure



Use **Trout**
at Ellerslie Brook, Prince Edward Island.
Tag is bent into circular form and applied around lower jaw at side.
Scale of Reward For tag ..... 10 cents
Reception Office Atlantic Biological Station, St. Andrews, New Brunswick.

CANADA

Marking Institution Department of Fisheries, Province of Quebec.

Type Monel metal or nickel strip bent into the shape of a ring.
(a) Small strip, 59 mm. long, 3 mm. wide, weighing 0·85 grams.
(b) Larger strip, 78 mm. long, 3·3 mm. wide, weighing 1·12 grams.
Both kinds stamped **D. P. Q.** and a number.

Figure

Use **Eel, Shad, Striped Bass,** and **Sturgeon.**
With sturgeon, tags are passed through the skin and flesh in front of the dorsal fin. With the other species, tags are inserted in the lower jaw through a hole made under and inside the mandible by the pointed end of the tag.

Scale of Reward For the tag and information on time, place of capture, and size of fish . . . . . 1.00 dollar

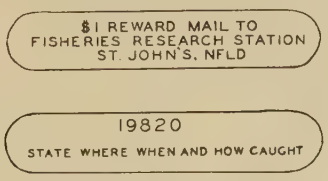
Reception Office Biology Laboratory, Department of Fisheries, Quebec.

These tags are described by V. D. Vladykov, "Movements of Quebec Shad (*Alosa sapidissima*), as demonstrated by tagging", *Nat. Canadien*, 1950, **77**, pp. 121—135, Quebec, Canada.

Marking Institution Fisheries Research Board of Canada.

Type Laminated plastic strips of various colours and sizes.

Figure



Use **Cod** and **Salmon.**
On cod as internal tag and as external tags attached to cod and salmon by nickel wire.

Scale of Reward For tags and information . . . . . 1.00 dollar

Reception Office Newfoundland Fisheries Research Station, St. John's, Newfoundland.

CANADA

Marking Institution Department of Fisheries, Province of Quebec.

Type Narrow strip of laminated vinylite (25 mm. × 8 mm. × 0·5 mm.), attached by a stainless steel split wire ring, 19 mm. in diameter. The thickness of the wire is 1 mm.
Inscribed "Département des Pêcheries, Québec" on one side, and a number and a letter on the other.

Figure

Use **Eel, Shad,** and **Striped Bass.**
The ring of this tag is attached by means of special pliers to the lower jaw of the fish.

Scale of Reward For the tag and information on time, place of capture, and size of fish ..... 1.00 dollar

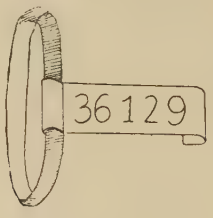
Reception Office Biology Laboratory, Department of Fisheries, Quebec.

A detailed description of this new type of tag will be published shortly.

Marking Institution Fisheries Research Board of Canada.

Type Monel metal, stamped with a number (1¼"×¼").

Figure



Use **Lobster.**
One end is hooked over the posterior margin of the carapace; the other end is bent back to hold a rubber band which is passed around the rostrum. The tags are lost on moulting.

Scale of Reward For tag ..... 25 cents

Reception Office Atlantic Biological Station, St. Andrews, New Brunswick.

CANADA

Marking Institution Fisheries Research Board of Canada.

Type Two Monel metal disks joined by two pure nickel wires. One is stamped "Canada Fisheries" with a number, the other is unmarked.

Figure

Use **Harp Seal** (*Phoca groenlandica*).
They are placed on the tail, near the tip, wired together through the flesh round the tail vertebrae.

Scale of Reward For tails with tags attached, and information . . . . . 2.00 dollars
A piece of the lower jaw containing the canine tooth is also asked for.

Reception Office Atlantic Biological Station, St. Andrews, New Brunswick.

DENMARK

Marking Institution Danmarks Fiskeri- og Havundersøgelser, Charlottenlund Slot, Danmark.
Grønlands Fiskeriundersøgelser, Charlottenlund Slot, Danmark.

Type Two ebonite disks attached by a silver wire — Petersen disks.
One stamped with one of the following sets of letters (the three last ones are used only in Greenland and Faroe waters) and a number — **DA, DAN, DaG, G, DaF.**
In future tagging experiments the following identification system will be adopted:—

Da 1	and number:		Transition area.
Da 2	„	„	North Sea.
Da 3	„	„	North Atlantic (Faroe, Iceland).
Da 4	„	„	Greenland.

Figure

Use **Plaice, Halibut, Flounder,** other species of **flatfish, Cod,** and **Greenland Shark.**
The disk is attached by thrusting the silver wire between the interradii of the dorsal fin of the flatfish. For cod and halibut the tag is fixed to the centre of the gill-cover, either between or through the opercular bones. For Greenland shark the tag is attached to the anterior part of the dorsal fin, in the pectoral fin, or in the cheek.

Scale of Reward For each recaptured fish with full information on place and date of capture ..... 5 kr.
In Danish waters the market value of the fish is also paid.

Reception Office Danmarks Fiskeri- og Havundersøgelser, Charlottenlund Slot, Danmark.
Grønlands Fiskeriundersøgelser, Charlottenlund Slot, Danmark.

DENMARK

Marking Institution Danmarks Fiskeri- og Havundersøgelser, Charlottenlund Slot, Danmark.
Grønlands Fiskeriundersøgelser, Charlottenlund Slot, Danmark.

Type Circular celluloid disk with central perforation. Diameter 7 mm. Attached by means of a fine stainless steel wire.
Stamped **Da** and a number.

Figure

Use **Trout.**
The tag is attached behind the dorsal fin.

Scale of Reward For each recaptured fish with full information .. .. 5 kr.

Type Pear-shaped plate of "Alcathene" attached by a nylon thread (preferably spun) or fine stainless steel wire.
It is attached by means of a specially devised darning needle "Bertelsen tag".
Stamped **Da** or **DANA**; in Greenland waters **DAG**.

Figure

Use **Herring** and **Trout** in Danish waters, small **Cod, Salmon** and **Char** in Greenland waters.
The tag is attached in front of the dorsal fin.

Scale of Reward For each recaptured fish with full information,
Herring ..... 10 kr.
Trout, cod, char ..... 5 kr.

Reception Office Danmarks Fiskeri- og Havundersøgelser, Charlottenlund Slot, Danmark.
Grønlands Fiskeriundersøgelser, Charlottenlund Slot, Danmark.

DENMARK

Marking Institution Danmarks Fiskeri- og Havundersøgelser, Charlottenlund Slot, Danmark.
Grønlands Fiskeriundersøgelser, Charlottenlund Slot, Danmark.

Type See Norway, Lea Hydrostatic tag, p. 270.
Stamped **D**, or **Da**, and a number.

Figure See Norway, p. 270.

Use **Herring** in Danish waters, small **Cod** (below 50 cm. length), **Salmon,** and **Char** in Greenland waters.
The tag is attached in front of the dorsal fin (cod, 2nd dorsal fin).

Scale of Reward For each recaptured herring with full information ..... 10 kr.
Cod and char ..... 5 kr.

Type Thin, rectangular red plastic strip attached by a nylon thread (preferably spun), or fine silver or stainless steel wire. "Danish flag".
Stamped **DA** and a number.

Figure

Use **Herring.**
The tag is attached in front of the dorsal fin.
Plaice.
Used in connexion with the ebonite disk tag for "double tagging". Notices are published in the Danish press instructing the fishermen to cut off the red plastic strip and immediately release the fish where captured; length of fish, date, and position should be reported when the plastic strip is returned to the marking institution. The method has been a success in the North Sea.

Scale of Reward For each recaptured fish with full information,
Herring ..... 10 kr.
Plaice ..... 5 kr.

Reception Office Danmarks Fiskeri- og Havundersøgelser, Charlottenlund Slot, Danmark.
Grønlands Fiskeriundersøgelser, Charlottenlund Slot, Danmark.

DENMARK

Marking Institution Danmarks Fiskeri- og Havundersøgelser, Charlottenlund Slot, Danmark.
Grønlands Fiskeriundersøgelser, Charlottenlund Slot, Danmark.

Type Paper tag impregnated with celluloid. Attached by a fine stainless steel wire.
Stamped **D. A.** and a number, or a number only, on one side. Address of reception office etc. is given on the other side.

Figure

Use **Salmon** and **Trout.**
The tag is attached in front of or behind the dorsal fin.

Scale of Reward For each recaptured fish with full information .. .. 5 kr.

Type The fish is marked by removal of a fin or fins.
The fin is either cut off or removed by means of an electric searing needle.

Use **Trout.**
The following methods have been practised:—
(a) Removing the adipose fin by electric searing needle.
(b) Cutting off the left ventral fin.
(c) „ „ „ right ventral fin.
(d) „ „ „ both ventral fins.
(e) „ „ „ right pectoral fin.

Scale of Reward For each recaptured fish with full information .. .. 5 kr.

Reception Office Danmarks Fiskeri- og Havundersøgelser, Charlottenlund Slot, Danmark.
Grønlands Fiskeriundersøgelser, Charlottenlund Slot, Danmark.

It should be noted that from time to time small numbers of different species of fish have been marked with several other types of tags, not mentioned above. These tags are invariably stamped DA and a number.

ENGLAND

Marking Institution Marine Biological Association of the United Kingdom, Plymouth.

Type One silver disk attached by a silver wire to tail. Stamped **PH** and a number.

Figure

Use **Raiidae.**
No active tagging at present, but future experiments would use the same tags.

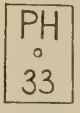
Scale of Reward For tail, with mark in position, together with the following information:— width measured across the wings to nearest 1/4 inch or 0·5 cm.; locality where captured, and date of capture 2/6
For mark only, with above information 2/-
For tail and mark only, or mark only ..... 6 d.
Postage is refunded. The finder is informed of date and place of liberation.

Reception Office Director, The Laboratory, Citadel Hill, Plymouth.

Marking Institution Marine Biological Association of the United Kingdom, Plymouth.

Type Two vulcanite plates, the upper one being white and circular or rectangular in shape (slightly modified from the ordinary type of plaice mark) attached to wing.
Upper plate stamped **PH** and a number.

Figure



Use No active tagging at present, but future experiments would use the same tags.

Scale of Reward For mark, together with the following information:— width measured across the wings to nearest 1/4 inch or 0·5 cm.; locality where captured, and date of capture 2/-
For mark 1/-
Postage is refunded. The finder is informed of date and place of liberation.

Reception Office Director, The Laboratory, Citadel Hill, Plymouth.

ENGLAND

Marking Institution Ministry of Agriculture and Fisheries, London.

Type

(a) Two 12·5 mm. ebonite disks, black or coloured, attached by silver wire to gill cover. Upper disks stamped **E** plus a second letter, with serial number below.

(b) Experimental variant of (a) with lower disk and pin of a stainless metal.

(c) Lea Hydrostatic tag (*q. v.*) attached to back muscle of fish.

(d) Two 15·5 mm. ebonite buttons or other tag, with similar bridle, black, attached by silver wire. Upper button stamped **E** plus a second letter, with a serial number below.

(e) Hodgson tag. This is made of flat transparent plastic material, embedded in which instructions to finder are printed on a yellow base. The tag measures 37·5×10 mm. and is approximately ·6 mm. thick. It is attached to the back of the fish by a nylon and wire toggle.

Figure

(a) (d) (e)

Use (a) and (b) **Cod.** (c) **Cod** and **Herring.**
(d) **Plaice.** (e) **Herring.**

Scale of Reward

Cod from Barents Sea.
For fish and tag with full recapture data . . . 5/-
For tag with full recapture data and head or ear-stones 5/-
For tag and recapture data 2/-
Postage is refunded and the finder informed of liberation data.

Plaice.
For fish and tag with full recapture data 2/-
For the tag only, with full recapture data . . . 1/-
For the mark without particulars . . . . . 6 d.
The market value of the fish may also be claimed.
Information will be supplied to the finder as to where and when the fish was tagged and liberated.

Herring.
For the tag with or without the fish 10/-

Reception Office Director, Fisheries Laboratory, Lowestoft, Suffolk, or the Ministry's local Fishery Officer or Collector.

ENGLAND

Marking Institution Freshwater Fisheries Department, Ministry of Agriculture and Fisheries, 3, Whitehall Place, London, S. W. 1.

Type

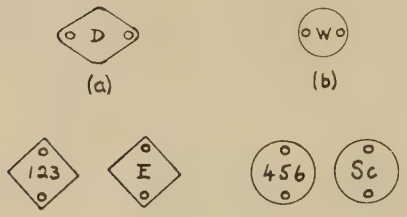
(a) Oblong silver disks $^{5}/_{16}$″ long with two holes. Stamped various letters of the alphabet.

(b) Circular silver disks $^{3}/_{16}$″ diameter with two holes. Stamped various letters of the alphabet.

(c) Square cellulose nitrate plates, 5 mm. square, 0·04 inches thick, with two holes. Stamped various numbers and letter E on the reverse side.

(d) Circular cellulose nitrate disks, 6 mm. diameter and 0·04 inches thick, with two holes. Stamped various numbers and letters Sc on the reverse side.

Figure



(a) (b) (c) (d)

Use

Salmon and **Sea-Trout Smolts.**

The tag is attached by a silver wire to the base of the dorsal fin. Types (b) and (d) to be used by the Scottish Home Department for experiments carried out in conjunction with those of the Ministry of Agriculture and Fisheries. (See note on Scottish tags, p. 274).

Scale of Reward For each tag returned with a note on the place, date, and method of capture, the length and weight of the fish, and a few scales from the shoulder 5/-

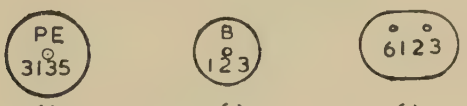
Reception Office Chief Inspector (Salmon and Freshwater Fisheries), Ministry of Agriculture and Fisheries, 3, Whitehall Place, London S. W. 1.

ENGLAND

Marking Institution Marine Biological Station, Port Erin, Isle of Man.

Type
(a) Black circular plastic disks, $^5/_8$″ diameter, with central hole. Stamped **P. E.** and a number.
(b) Circular Monel metal disks, $^1/_2$″ diameter, with central hole. Stamped **B 001—B 500.**
(c) Oval Monel metal disks, $^3/_4$″×$^1/_2$″, with two holes. Stamped 6001—6500.

Figure



(a) (b) (c)

Use **Escallops.**
The mark is attached to the flat valve of the shell.

Scale of Reward
For each living escallop, with mark in position, together with information as to locality and date of capture, three times the current market value.
For each living escallop, with mark in position, without information, twice the current market value.
For each shell, with mark in position, found empty while dredging, with information as to locality and date of capture ..... 3 d.
In the case of escallops returned by wholesalers and dealers, a fixed sum of 1/6d. is paid for each escallop complete with details; postage is refunded. The finder is informed of the place and date of liberation.

Reception Office Director, Marine Biological Station, Port Erin, Isle of Man.

FINLAND

See under Sweden, p. 278.

FRANCE

Marking Institution Institut Scientifique et Technique des Pêches Maritimes, 59, avenue Raymond-Poincaré, Paris.

Type Two ebonite disks, attached by a silver wire. One disk stamped R. F. and a number. Diameters, 12 mm. and 15 mm.

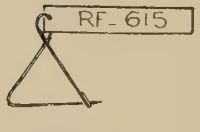
Figure

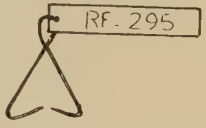
Use **Cod, Hake, Plaice** (occasionally), **Whiting, Red Mullet.**

Scale of Reward
For the fish and mark, with information as to date and place of capture . . . . . 500 F.
For the mark alone, with the same information . . . . . 250 F.

Type Yellow plate of celluloïd and two types of pins of stainless steel.

Figure





Use **Pilchard, Herring, Cod.**

Scale of Reward
For the fish and mark, with information as to date and place of capture . . . . . 500 F.
For the mark alone, with the same information . . . . . 250 F.

Type Hameçon double à bosse cassante, portant bague inoxydable rouge ou verte avec marque R. F. et un numéro.

Use **Thon rouge, Germon, Bonites** et autres **Thonidés.**

Reception Office
Institut Scientifique et Technique des Pêches Maritimes, 59, avenue Raymond-Poincaré, Paris (16ème).
Laboratoire de Boulogne s/Mer, boîte postale 42.
Laboratoire de La Rochelle, 74, Allées du Mail.
Service de l'Inscription Maritime sur le Littoral.

GERMANY

Note. No large-scale marking experiments have been carried out in Germany since the war. Up to and during the war, various species of fish were marked with the marks described below. Some of the marking institutions are no longer in existence (names in brackets): their work is carried on by the institutions named in the first place under "Reception Office".

Marking Institution
(a) Biologische Anstalt Helgoland.
(b) (Deutscher Seefischereiverein.)
(c) (Deutsche wissenschaftliche Kommission für Meeresforschung, Abt. Ostsee.)
(d) (Reichsanstalt für Fischerei, Institut für Ostseefischerei.)

Type
So-called "Scottish" plaice mark consisting of two disks made of black vulcanized rubber (ebonite) joined by a silver wire.
Stamped with a number and **DH** for (a), **D** for (b) and (d), **D. Ha** for (c).

Figure

Use
(a) **Soles** and other **flatfish** in the North Sea.
(b) **Dabs** in the Belt Sea and central Baltic, North Sea **Plaice** transplanted to the Belt Sea, **Turbot** in the Belt Sea.
(c) **Plaice** and **Flounders** of the central Baltic transplanted to the Belt Sea, and **Turbot** from the central Baltic transplanted to the North Sea.
(d) **Flounders** transplanted to the Rügen Area, and **Flounders** in the eastern Baltic.

Scale of Reward
On forwarding the whole fish with mark and information as to place and date of capture, and gear used . . . . . 2.— DM
In the case of larger fish the market-price is paid in addition.
On forwarding the mark alone with the above information . . . . . 1.— DM

Reception Office
(a) Biologische Anstalt Helgoland, z. Zt. List/Sylt.
(b) and (d) Bundesanstalt für Fischerei, Institut für Küsten- und Binnenfischerei, Hamburg 36, Neuerwall 70—74.
(c) Institut für Meereskunde der Universität Kiel, Hohenbergstr. 2.
Fishery Associations.
State Fishery officials.
Inspector's Office at fishery ports.

GERMANY

Marking Institution (Deutscher Seefischereiverein.)

Type Silver wire 1/3 mm. thick, bearing coloured glass beads.
In earlier experiments an aluminium disk stamped **D** and a number was used.

Figure

Use **Brook** and **Rainbow Trout** marked in the southern Baltic. The mark is fastened behind the dorsal fin.
Eel in the same area.

Scale of Reward On forwarding the whole fish with the mark and information as to place and date of capture, and gear used . . . . . 2.— DM
The market value of the fish is paid in addition.

Reception Office Bundesanstalt für Fischerei, Institut für Küsten- und Binnenfischerei, Hamburg 36, Neuerwall 70—74.
Fishery Associations.
State Fishery Officials.

Remarks In future experiments the silver wire may be replaced by a perlon thread, and the aluminium disks by silver disks.

Marking Institution (Deutscher Seefischereiverein.)

Type Small silver spatulate plate.
Stamped **DFV** and a number.

Figure

Use The mark was formerly used for marking **Eels** and may be used again in future experiments, stamped **D** and a number. The mark is fastened by the point being pushed through the skin alongside the base of the dorsal fin.
Not in use at present.

Reception Office Bundesanstalt für Fischerei, Institut für Küsten- und Binnenfischerei, Hamburg 36, Neuerwall 70—74.

GERMANY

Marking Institution Landesfischereiverband Baden Freiburg, Erbprinzenstr. 2.

Type "Rugela" mark. Metal button with coloured celluloid disk.
Stamped with a number.

Figure

Use Marking of ***Barbus fluviatilis, Abramis brama, Abramis björkna, Scardinius erythophthalmus, Squalius cephalus, Chondrostoma nasus, Esox lucius, Lucioperca sandra, Perca fluviatilis.*** Rhine and tributaries. The mark is fastened to the gill covers with the special "Rugela" pliers.

Scale of Reward On forwarding the mark and information as to the place, date, and gear of capture . 3.— DM

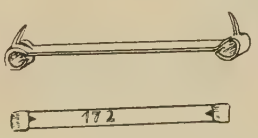
Reception Office Dr. W. K o c h, Karlsruhe-Rüppurr, Bussardweg 41.
Deutscher Fischereiverband, Hamburg.

For description of this tag — as well as the "Fima" type — see a paper by W. K o c h on fish marking in *Zeitschrift für Fischerei*, 1937, Vol. 35.

Marking Institution Institut für Fischereiwissenschaft der Universität, Hamburg 36, Holstenwall 24.

Type Surgical clips 18 mm. by 3 mm.
Stamped with a number.

Figure



Use **Flatfish** in inshore waters. Fastened to the dorsal part of the caudal peduncle. The results of tests have not yet been published.

Scale of Reward On forwarding the clips . . . . . 0.25 DM

Reception Office Institut für Fischereiwissenschaft der Universität, Hamburg 36, Holstenwall 24.

ICELAND

Marking Institution University Research Institute, Fishery Department, Reykjavík.

Type Two black ebonite disks joined by a silver wire. One stamped **ISL** and a number.

Figure

Use **Cod** and **Plaice.**
The disk is fixed by thrusting the silver wire between the interradii of the dorsal fin of the plaice or between the opercular bones in the gill-cover of the cod.

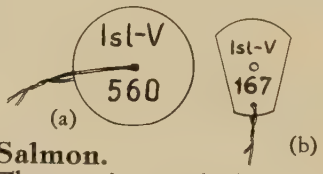
Scale of Reward 5 krónur.

Reception Office Fiskideild, Borgartún 7, Reykjavík.

Marking Institution Inspector of Freshwater Fisheries, Reykjavík.

Type (a) Black ebonite disk stamped **Isl-V** and a number.
(b) As (a) but the disk is smaller.

Figure



Use **Salmon.**
The tag is attached to the fish in front of the dorsal fin by means of a silver wire.

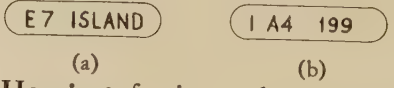
Scale of Reward No reward.

Reception Office Veiðimálastjóri, Tjarnargötu 10, Reykjavík.

Marking Institution University Research Institute, Fishery Department, Reykjavík.

Type (a) A nickel plated steel tag about 20×3×1 mm., stamped **ISLAND**, a serial letter, and a number.
(b) As (a) but stamped **I** instead of **ISLAND**.

Figure



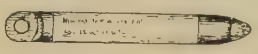
Use **Herring,** for internal tagging.

Scale of Reward 15 krónur.

Reception Office Fiskideild, Borgartún 7, Reykjavík.

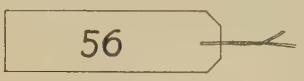
ICELAND

Marking Institution Inspector of Freshwater Fisheries, Reykjavík.
Type Lea Hydrostatic tag.

Figure 

Use **Salmon.**
Attached by steel wire.
Scale of Reward No reward.
Reception Office Veiðimálastjóri, Tjarnargötu 10, Reykjavík.

Marking Institution Inspector of Freshwater Fisheries, Reykjavík.
Type A piece of cardboard covered with plastic with a number on one side and text on the other.

Figure 

Use **Trout.**
Attached by steel wire.
Scale of Reward No reward.
Reception Office Veiðimálastjóri, Tjarnargötu 10, Reykjavík.

Marking Institution Inspector of Freshwater Fisheries, Reykjavík.
Type Alcathene plate numbered on one side.

Figure

Use **Trout** and **Char.**
Attached by nylon thread or silver wire.
Scale of Reward No reward.
Reception Office Veiðimálastjóri, Tjarnargötu 10, Reykjavík.

Marking Institution Inspector of Freshwater Fisheries, Reykjavík.
Type Piece of plastic cloth with numbers on one side.

Figure

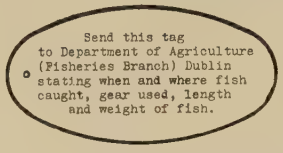
Use **Trout** and **Char.**
Attached by silver wire.
Scale of Reward No reward.
Reception Office Veiðimálastjóri, Tjarnargötu 10, Reykjavík.

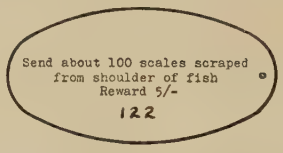
IRELAND

Tagging Institution Department of Agriculture, Fisheries Branch, Dublin.

Type (1) Lea Hydrostatic tag. See p. 270 and 276.
(2) Celluloid tags.

Figure





Use The circular celluloid tag for **Escallops** and the remainder for **Salmon, Sea Trout,** and **Brown Trout.**

Scale of Reward For a tag with particulars of tagged fish recaptured 5/-

Reception Office Department of Agriculture, Fisheries Branch, Dublin.

NETHERLANDS

Marking Institution Government Institute of Fishery Investigations, Oost Indisch Huis, Amsterdam.

Type Plastic strip with rounded edges, colourless or painted red; stamped with a number only.

Figure

Use **Carp** in Lake Ijssel.
The tag is attached with a silver wire through the muscles in front of the dorsal fin.

Scale of Reward For foreign-caught fish, if the tag is returned together with information as to date and locality of capture, and length or weight of fish ..... f. 2.—

Reception Office Rijksinstituut voor Visserij-onderzoek (Government Institute of Fishery Investigations), Oost Indisch Huis, Amsterdam.

NORWAY

Marking Institution Director of Fisheries, Institute of Marine Research, Bergen.

Type Two round ebonite disks attached to the gill cover by a silver wire.
One disk stamped **N** and two numbers.

Figure

Use **Cod.**
Scale of Reward Kr. 5.00.
Reception Office Fiskeridirektoratets Havforskningsinstitutt, Postboks 226, Bergen.

Marking Institution The same type of tag is also used by the University of Oslo, Biological Laboratory, Oslo.
Use **Plaice.**
Scale of Reward Kr. 2.00.
Reception Office Biologisk Laboratorium, Fredriksgate 3, Oslo.

Marking Institution Director of Fisheries, Institute of Marine Research, Bergen.

Type Two round celluloid disks attached to the gill cover by a silver wire. The outer disk, which is white, is stamped **N** and two numbers. The other disk, which is red, bears the full address of the "Fiskeridirektorat".

Figure

Use **Cod.**
Scale of Reward Kr. 5.00.
Reception Office Fiskeridirektoratets Havforskningsinstitutt, Postboks 226, Bergen.

NORWAY

Marking Institution Director of Fisheries, Institute of Marine Research, Bergen.

Type A celluloid disk, with one side white, the other red, stamped with **N** and two numbers, and the address of the "Fiskeridirektorat".

Figure

Use **Mackerel.**
The tag is fixed dorsally by nylon.

Scale of Reward Kr. 2.50.

Reception Office Fiskeridirektoratets Havforskningsinstitutt, Postboks 226, Bergen.

Marking Institution Director of Fisheries, Institute of Marine Research, Bergen.

Type A round disk of yellow plastic with a black triangular section in the centre. It is stamped with the address of the "Fiskeridirektorat" and a number, or with **N** and one or two numbers.

Figure

Use **Cod.**
The disk is fixed to the gill cover by a silver wire which is anchored to a smaller disk on the inner side of the gill cover.

Scale of Reward Kr. 5.00.

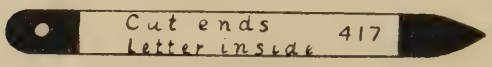
Reception Office Fiskeridirektoratets Havforskningsinstitutt, Postboks 226, Bergen.

NORWAY

Marking Institution Director of Fisheries, Institute of Marine Research, Bergen.

Type The Hydrostatic tag constructed by Mr. Einar Lea. A watertight tube of celluloid, coloured yellow and blue, containing a slip of paper instructing the finder what to do with the tag and the fish, and bearing a serial number and the address of the "Fiskeridirektorat". The tag is fixed dorsally or to the gill cover by stainless steel wire, or nylon.

Figure



Use **Cod, Mackerel, Herring.**

Scale of Reward
Cod ..... kr. 5.00
Herring ..... kr. 10.00
Mackerel ..... kr. 2.50

Reception Office Fiskeridirektoratets Havforskningsinstitutt, Postboks 226, Bergen.

Marking Institution Inspector for Freshwater Fisheries.

Type As above.

Use **Salmon** and **Sea Trout.**

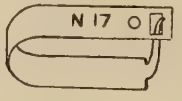
Scale of Reward
Salmon ..... kr. 5.00
Sea Trout ..... kr. 3.00

Reception Office Inspector for Freshwater Fisheries, Department of Agriculture, Kronprinsensgate 4 B, Oslo.

Marking Institution Director of Fisheries, Institute of Marine Research, Bergen.

Type Strap tags of Monel metal stamped **N** and two numbers.

Figure



Use **Cod, Halibut.**

The tag is fixed to the rear part of the gill cover.

Scale of Reward Kr. 5.00.

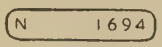
Reception Office Fiskeridirektoratets Havforskningsinstitutt, Postboks 226, Bergen.

NORWAY

Marking Institution Director of Fisheries, Institute of Marine Research, Bergen.

Type An internal tag of stainless steel or nickel-plated iron, stamped **N** and a number, and sometimes another letter also to designate the series.

Figure



Use **Herring.**

Scale of Reward Kr. 10.00.

Reception Office Fiskeridirektoratets Havforskningsinstitutt, Postboks 226, Bergen.

Marking Institution Director of Fisheries, Institute of Marine Research, Bergen.

Type A cylinder of alcathene film, fixed dorsally by a stainless steel wire, or by nylon. Instructions as to what to do with the fish and the tag are revealed by unrolling the cylinder.

Figure

Use **Herring** and **Mackerel.**

Scale of Reward

Herring	kr. 10.00
Mackerel	kr. 2.50

Reception Office Fiskeridirektoratets Havforskningsinstitutt, Postboks 226, Bergen.

SCOTLAND

Tagging Institution Scottish Home Department, Edinburgh.

Type Two ebonite or plastic disks attached by a silver wire.

One disk stamped Sc followed by a serial number, or letter, with an individual number below.

Figure

Use **Plaice, Lemon Sole, Dab, Halibut,** and **Skate.**

Scale of Reward For fish with tag *in situ* and full particulars of capture (i.e., position, date, type of gear in use) 2/-

For tag alone, with full particulars 1/-

For tag alone, without particulars ..... 6 d.

Postal expenses incurred are refunded and the market value of fish received may also be claimed.

Reception Office The Director, Marine Laboratory of the Scottish Home Department, Wood Street, Torry, Aberdeen.

Note. As it is not the practice at present to forward a tagged fish to the country of its origin when landed at a foreign port, the particulars required are — Length of fish from tip of snout to end of caudal fin (and breadth in the case of Skate), weight (gutted or ungutted), sex and state of development of sexual organs. In the case of Plaice the otoliths of the fish are desired, and for Lemon Sole a small sample of scales taken from the upper surface of the fish at a position on the lateral line about two-thirds of the length from the snout.

Tagging Institution Scottish Home Department, Edinburgh.

Type Green plastic band secured by small stainless steel metal plate. On metal plate one side is stamped SC; on the other side, a serial letter and number.

Figure

Use **Herring** (1948—50).

Scale of Reward For return of fish and tag with details of capture 10/-

Reception Office The Director, Marine Laboratory of the Scottish Home Department, Wood Street, Torry, Aberdeen.

SCOTLAND

Tagging Institution Scottish Home Department, Edinburgh.

Type Two boat shaped pieces of coloured polystyrene, hollowed and fused together, and containing a paper strip, with possibly also a metal one, bearing a serial letter and number. Engraved on one side "Marine Lab., Aberdeen. Reward." Attached by a toggle made of nylon loop and wire rod.

Figure

Use **Herring.**

Scale of Reward For return of fish and tag with details of capture 10/-

Reception Office The Director, Marine Laboratory of the Scottish Home Department, Wood Street, Torry, Aberdeen.

Tagging Institution Scottish Home Department, Edinburgh.

Type Plastic flag. Strip of red or green plastic bearing letters S. C. and a serial letter and number. Attached by nickel wire.

Figure

Use **Herring** and **Haddock.**

Scale of Reward For return of fish and/or tag with details of capture:

Haddock 2/6

Herring 10/-

Reception Office The Director, Marine Laboratory of the Scottish Home Department, Wood Street, Torry, Aberdeen.

SCOTLAND

Tagging Institution Scottish Home Department, Edinburgh.

Type Red plastic band bearing letters S. C. and serial letter and number, passed loosely round the body and secured by nickel wire just anterior to dorsal fin.

Figure

Use **Haddock.** (1951—52).

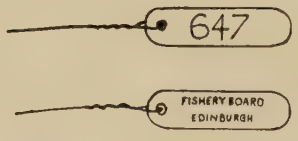
Scale of Reward For return of fish and/or tag with details of capture 2/6

Reception Office The Director, Marine Laboratory of the Scottish Home Department, Wood Street, Torry, Aberdeen.

Tagging Institution Scottish Home Department, Edinburgh.

Type Red celluloid tag, secured by a single silver wire. Tag bears a number on one face and the words "Fishery Board Edinburgh" on the other.

Figure



Use **Sea Trout.**

Scale of Reward For tag, date and place of capture, length and weight of fish, sex (if possible), and some scales 5/-

Reception Office The Director, Marine Laboratory of the Scottish Home Department, Wood Street, Torry, Aberdeen.

Note. See also under England, Ministry of Agriculture and Fisheries, page 258.

SCOTLAND

Institution Scottish Home Department, Edinburgh.

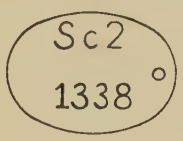
N o t e: The Lea Hydrostatic tag (see Norway and Sweden, pp. 270 and 276) is used by the Scottish Home Department, principally for **Salmon** and **Herring**, but it has also been tried for **Haddock**. The reward for the return of a Salmon tag, with information regarding date and place of capture of the fish, its length and weight, sex (if possible), and some scales, is 5/-.

To provide comparison with hydrostatic tags a small number of the "D" type Salmon and Sea Trout tag, which was described in the previous "Guide" (Journ. du Cons., **7**, p. 161, was used on these species by Ministry of Agriculture and Fisheries staff in 1952. Any recoveries of such tags could be notified either to the Ministry or to the Scottish Home Department, Marine Laboratory, Aberdeen.

Tagging Institution Scottish Home Department, Edinburgh.

Type Oval copper disk.
Stamped **Sc** followed by a serial number with an individual number below.

Figure



Use **Crab** and **Lobster.**
Tag attached to one large claw by a wire.

Scale of Reward For tag with full particulars of capture of the animal (i.e., position, date, type of gear in use) 2/-
For tag, without particulars ..... 6d.
The postal expenses incurred are also refunded.

Reception Office The Director, Marine Laboratory of the Scottish Home Department, Wood Street, Torry, Aberdeen.

SWEDEN

Marking Institution Havsfiskelaboratoriet, Lysekil.
Type Upper disk of round ebonite, attached by silver wire to a round ebonite disk on the lower side. Upper disk stamped Sv and two numbers.

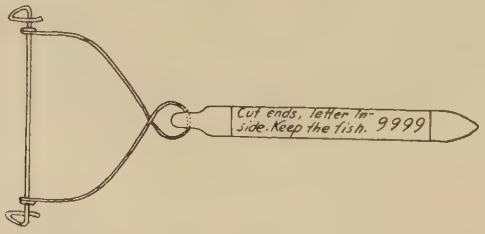
Figure

Use **Plaice, Flounder,** and **Turbot.**
The mark is fixed through the posterior part of the body.
Scale of Reward For each mark returned ..... 2 Swedish crowns
Reception Office Havsfiskelaboratoriet, Lysekil.

Marking Institution Havsfiskelaboratoriet, Lysekil.
Type Two round ebonite disks, connected by a silver wire.
Upper disk stamped Sv and two numbers.
Figure See Plaice, Flounder, and Turbot above.
Use **Cod.**
Fixed in the musculature behind the last dorsal fin.
Scale of Reward For each mark returned ..... 3 Swedish crowns
Reception Office Havsfiskelaboratoriet, Lysekil.

Marking Institution Havsfiskelaboratoriet, Lysekil.
Type Lea Hydrostatic tag. Celluloid tube, yellow with blue end; ca. 40 mm. long by 4 mm. diameter. Rolled-up paper inside giving complete instructions to the finder.

Figure



Use **Herring.**
Fixed by means of a wire hinge of stainless steel through the musculature, some inches in front of the dorsal fin.
Scale of Reward For each tag returned ..... 8 Swedish crowns
Reception Office Havsfiskelaboratoriet, Lysekil.

SWEDEN

Marking Institution Havsfiskelaboratoriet, Lysekil.

Type Small oval silver plate mounted on a flat silver pin.
Stamped SV and a number.

Figure

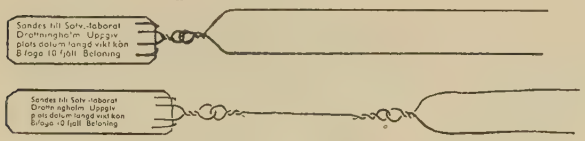
Use **Eel.**
With a curved awl two holes are made on one side of the Eel under the anterior part of the dorsal fin and the pin is then passed through these holes. Afterwards first the pin end and then the plate are bent round and pressed close to the body surface.

Scale of Reward For each mark returned ..... 3 Swedish crowns

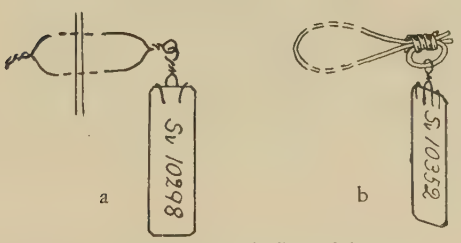
Reception Office Havsfiskelaboratoriet, Lysekil.

Marking Institution Migratory Fish Committee.

Type Celluloid-coated cardboard with text printed on one side and the letters Sv and a number written on the other. The letters Sk, Sm, and Sw have also been used. A small loop of stainless steel wire is fastened to the mark; this is looped through another loop with doubled stainless steel wires. Silver wire or nylon thread (platil) have also been used in place of stainless 1-ply steel wire.



Figure



Use Young **Salmon** and **Sea Trout.**
The two free ends of the wire are passed through the fish from the same side just below the dorsal fin and are twisted together on the opposite side. The mark thus moves freely on one side of the base of the dorsal fin.

Scale of Reward For each mark returned ..... 5 Swedish crowns

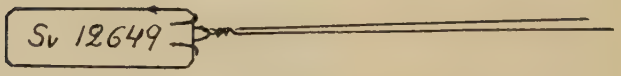
Reception Office Sötvattenslaboratoriet, Drottningholm.

SWEDEN

Marking Institution Migratory Fish Committee.

Type Celluloid-coated cardboard with text printed on one side and the letters Sv and a number written on the other side. (The letters S, SA, and Sb have also been used.) A doubled stainless steel wire is attached to the mark.

Figure



Use **Salmon** and **Sea Trout.**
The mark is attached to the base of the dorsal fin (fore or aft) or to the adipose fin.

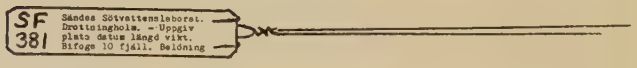
Scale of Reward For each mark returned ..... 5 Swedish crowns

Reception Office Sötvattenslaboratoriet, Drottningholm.

Marking Institution The Swedish and the Finnish Migratory Fish Committees jointly.

Type Celluloid-coated cardboard with photographic copy of typewritten text. One side of the mark bears the Finnish text, the other side, the Swedish text together with the letters SF and a number.

Figure



Use **Salmon.**
The mark is attached to the base of the dorsal fin.

Scale of Reward For each mark ..... 5 Swedish crowns

Reception Office Sötvattenslaboratoriet, Drottningholm, or Lantbruksstyrelsen, Helsingfors.

UNITED STATES OF AMERICA

Marking Institution Marine Laboratory, University of Miami, Coral Gables, Fla.

Type Oval, Monel metal disk. Stamped "U. OF MIAMI REWARD" and a number.

Figure

Use **Sailfish** (*Istiophorus americanus*).
The disk is fastened to the bill of the sailfish with Monel metal wire.

Scale of Reward For tag and information ..... 50 cents

Reception Office Marine Laboratory, University of Miami, Coral Gables, Fla.

Marking Institution North Atlantic Fishery Investigations of the U. S. Fish and Wildlife Service.

Type Pin and double celluloid disk, $1/2''$ in diameter.

Figure

Use **Haddock,** applied to gill cover with nickel pin.
Yellowtail Flounder (*Limanda ferruginea*), **Fluke** (*Paralichthys dentatus*), **Blackback Flounder** (*Pseudopleuronectes americanus*), etc., attached at nape of neck with a nickel pin.
Scallops, attached by nickel pin inserted through hole drilled through ear of hinge.

Scale of Reward For each tag returned ..... $ 1.00

Reception Office U. S. Fish and Wildlife Service, Washington, D. C.

UNITED STATES OF AMERICA

Marking Institution Bingham Oceanographic Laboratory, Yale University, New Haven, Connecticut.

Type White celluloid disk tags ($1/2$" diameter) connected by nickel pin.

Figure

Use Mainly **Winter Flounder** (*Pseudopleuronectes americanus*), various spp. of **Skates** etc.

Scale of Reward No reward.

Reception Office State Board of Fisheries and Game, Hartford, Connecticut.

Marking Institution New York State Conservation Department, Freeport, L. I., New York.

Type Celluloid disk.

Figure

Use At present on **Winter Flounder** (*Pseudopleuronectes americanus*) near nape of neck.
Will be used on ***Cynoscion regalis*** and other species if found suitable.

Scale of Reward For tags and information $1.00

Reception Office New York State Conservation Department, 65, West Sunrise Highway, Freeport, L. I., New York.

UNITED STATES OF AMERICA

Marking Institution U. S. Fish and Wildlife Service, U. S. Fishery Laboratory, Beaufort, North Carolina.

Type Petersen disk tags. Two plastic disks strung on nickel pin. One disk is stamped FISH & WILDLIFE SERVICE, WASHINGTON, D. C. and REWARD and number.

Figure

Use **Shad** (*Alosa sapidissima*).
The stamped disk is strung on the three-inch nickel pin against the head of the pin; the pin is inserted through the fish's back about 1/4 inch behind and below the anterior insertion of the dorsal fin; the other disk is fitted on the protruding pin; excess wire is cut off; the pin is twisted in a loop which presses both disks against the fish.

Reward ..... 50 cents

Reception Office Fish and Wildlife Service, Washington, D. C., and U. S. Fishery Laboratory, Beaufort, North Carolina.

Marking Institution Chesapeake Biological Laboratory.

Type Petersen disk, non-corrosive metal pin.

Figure

Use **White Perch** (*Morone americana*).
Tags fastened through back below dorsal fin.

Scale of Reward For tags and information ..... $ 1.00

Reception Office Through U. S. Fish and Wildlife Service to Chesapeake Biological Laboratory, Solomons, Maryland.

UNITED STATES OF AMERICA

Marking Institution Marine Laboratory, University of Miami, Coral Gables, Fla.

Type Two red plastic disks joined by a pure nickel wire. One stamped "MARINE LAB. UNIV. OF MIAMI. RETURN WHOLE FISH, REWARD"; the other has a number.

Figure

Use **Mullet** (*Mugil cephalus*).
They are placed below the dorsal fin, above the lateral line.

Scale of Reward For tags and information . . . . . 50 cents
Return of the whole fish is requested.

Reception Office Marine Laboratory, University of Miami, Coral Gables, Fla.

Marking Institution Connecticut State Board of Fisheries and Game.

Type Laminated vinylite disk showing serial number on one side and "RETURN TAG FISH & GAME HARTFORD" on the other side.

Figure

Use **Shad** in Connecticut River.
Attached to cheek (usually left cheek) by stainless steel rivet.

Scale of Reward None. Tagging information sent to persons turning in tags.

Reception Office Connecticut State Board of Fisheries & Game, State Office Building, Hartford 1, Connecticut.

UNITED STATES OF AMERICA

Marking Institution U. S. Fish and Wildlife Service Fishery Station and Woods Hole Oceanographic Institution, Woods Hole, Mass.

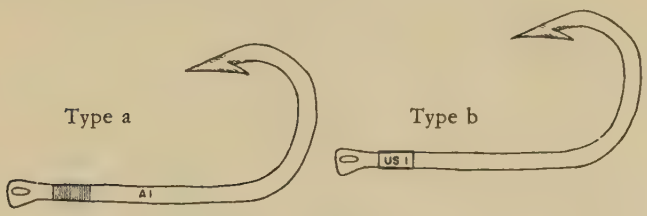
Type (a) Tuna hooks stamped with letters and numbers with $^1/_{16}$" steel dies. (A red plastic sleeve was also fitted to these hooks but is not considered as permanent as the numbers.) Letters used:— **A, B, C, F, G, J, K, L, M, P, R, S, V, W, AC, AH, AK, BG, BM, FF, FM, FV, GB, GC, GS, HA, HL, HM, HW, JF, JH, JM, JR, JT, JW, LM, NG, RS, SB, SS, US, WP, WS, FLG, HSG, 3D.**

(b) Tuna hooks fitted with ·015" stainless steel band around the shank bearing the letters **US** and a serial number. In some cases serial numbers are preceded by letters **A** or **B**.

Numbers used: US 1 through US 999

US A1 through US A99; US B1 through US B110

Figure



Use Large-sized **Bluefin Tuna** (*Thunnus thynnus*); may accidentally be lost also in **Marlin, Sharks,** and so forth. The hooks should be in mouth, throat, or stomach. Tagging done by accidentally or voluntarily breaking off of tuna hooked by sport fishermen using numbered hooks.

Scale of Reward For hooks and information ..... $ 2.00

Reception Office U.S. Fish and Wildlife Service, Washington, D.C.

UNITED STATES OF AMERICA

Marking Institution Marine Laboratory, University of Miami, Coral Gables, Fla.

Type A fish hook, 11—0 Dewitt, made of Monel metal. Serial number stamped on the shank. A Monel metal circular plate, 21 mm. in diameter, is stamped "Return Univ. of Miami, Fla. Reward". This plate has a circular hole near the top, large enough to admit the shank of the hook. The eye of the hook is opened and the plate slipped over it and bent around the shank just below the eye.

Figure

Use **Bluefin Tuna** (*Thunnus thynnus*).
The hook is fished on a light clip which is deliberately broken when the hook has been firmly set.

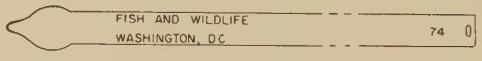
Scale of Reward For tag and information . . . . . $ 1.00

Reception Office Marine Laboratory, University of Miami, Coral Gables, Fla.

Marking Institution U. S. Fish and Wildlife Service, U. S. Fishery Laboratory, Beaufort, North Carolina.

Type Pointed metal strap tag, about 1 inch long when bent; stamped FISH & WILDLIFE SERVICE, WASHINGTON, D. C., and a number.

Figure



Use **Shad** (*Alosa sapidissima*).
These metal tags are bent so that the point passes through the operculum and small hole on blunt end of tag and locks.

Scale of Reward . . . . . 50 cents

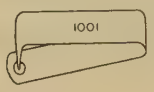
Reception Office U. S. Fish and Wildlife Service, Washington, D. C., and U. S. Fishery Laboratory, Beaufort, North Carolina.

UNITED STATES OF AMERICA

Marking Institution Marine Laboratory, University of Miami, Coral Gables, Fla.

Type Monel metal strap tag.

Figure



Use **Mullet** (*Mugil cephalus*).
Placed on the gill cover.

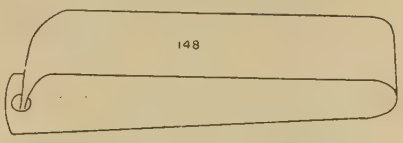
Scale of Reward For tags and information ..... 50 cents
Return of the whole fish is requested.

Reception Office Marine Laboratory, University of Miami, Coral Gables, Fla.

Marking Institution Marine Laboratory, University of Miami, Coral Gables, Fla.

Type Monel metal strap tag.

Figure



Use **Sailfish** (*Istiophorus americanus*), also a few **Little Tuna** (*Euthynnus alleteratus*), **Amber Jack** (*Seriola dumerlii*), and **White Marlin** (*Makaira albida*) have been marked with this tag. These tags have been put on the dorsal fin and on the gill cover.

Scale of Reward For tags and information ..... 50 cents

Reception Office Marine Laboratory, University of Miami, Coral Gables, Fla.

UNITED STATES OF AMERICA

Marking Institution State of Maine, Department of Sea and Shore Fisheries.

Type Celluloid disks.
(a) One white disk with name of marking institution and number.
(b) One red disk with directions and name of marking institution, used as backing for white disk.

Type

Use **Scallop** and **Lobster.**
When used on scallop, wired to upper valve over apical notch near hinge.
On lobster, pinned to telson or one of uropods.

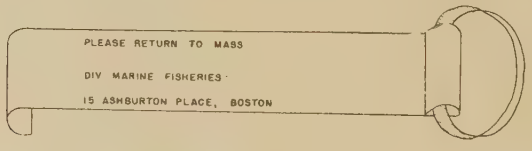
Scale of Reward No reward for information and returns.

Reception Office Fisheries Research Station, Dept. of Sea and Shore Fisheries, Boothbay Harbor, Maine.

Marking Institution Mass. Division of Marine Fisheries, 15, Ashburton Place, Boston, Mass.

Type A Monel metal tag measuring $2^{3}/_{8}'' \times {}^{5}/_{16}'' \times {}^{1}/_{32}''$, stamped: "PLEASE RETURN TO MASS. DIV. MARINE FISHERIES, 15, ASHBURTON PLACE, BOSTON", with a number on the back. The tag is bent somewhat S-shaped, with an elastic band fastened tightly at one end.

Figure



Use **Lobster** (*Homarus americanus*).
When in use these metal tags are hooked over dorsal posterior part of carapace shell, with elastic placed over rostrum, care being taken that the elastic does not go all the way down to restrict eye movement.

Scale of Reward None. Those returning tags receive a form letter giving location and date of release.

Reception Office Massachusetts Division of Marine Fisheries, 15, Ashburton Place, Boston, Mass.

UNITED STATES OF AMERICA

Marking Institution State of Maine Department of Sea and Shore Fisheries.

Type Metal strip tag.
(a) One series, number only, 42001 to 43000.
(b) One series, number on one side, "MAINE" on reverse.

Figure

Use **Lobster.**
Attached by elastic band over rostrum and tag hooked under posterior of carapace.

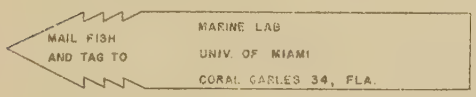
Scale of Reward No reward for information and return.

Reception Office Fisheries Research Station, Dept. Sea and Shore Fisheries, Boothbay Harbor, Maine.

Marking Institution Marine Laboratory, University of Miami, Coral Gables, Fla.

Type Plastic "dart", 40 mm. long, 6 mm. wide, and 0·5 mm. thick. The "head" of the tag is 14 mm. long, with serrations. Colour, white with black or red lettering.
One series bore the inscription "MAIL TAG TO MARINE LAB. UNIV. OF MIAMI, CORAL GABLES 34, FLA." on one side and "Tell where, when and by whom caught" on the other. A second series read "Mail fish & tag to Marine Lab. Univ. of Miami, Coral Gables 34, Fla.", with the same instructions as before on the obverse side.

Figure



Use **Spiny Lobster** (*Panulirus argus*).
The tag was thrust into the muscle at an angle of approximately 45°, between the first and second segments of the abdomen, on the dorsal side, and to the right of the midline.

Scale of Reward For tag and information . . . 25 cents, later $ 1.00
For fish, plus tag and information . . . . . $ 1.00, later $ 2.00

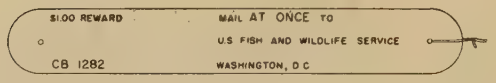
Reception Office Marine Laboratory, University of Miami, Coral Gables, Fla.

UNITED STATES OF AMERICA

Marking Institution Virginia Fisheries Laboratory, Gloucester Point, Virginia, in co-operation with Chesapeake Biological Laboratory, Solomons, Maryland, and the U. S. Fish and Wildlife Service.

Type One strip of red celluloid printed on one side with the following legend: "$ 1.00 REWARD mail AT ONCE to U. S. Fish and Wildlife Service, Washington, D. C." and a number. On the other side "STATE WHERE AND WHEN CAUGHT OR WHEN AND FROM WHOM PURCHASED".

Figure



Use **Blue Crab** (*Callinectes sapidus*).

These tags are attached by means of a length of thin surgical steel wire passing through a suture on the under side of the carapace, the tag itself dangles freely from the crab. This method of attachment has the advantage that the wire passes only through the soft parts of the crab and, therefore, is not shed when the crab moults. Its effectiveness has been demonstrated both in captivity and under natural conditions.

Scale of Reward For tags and information ..... $ 1.00

Reception Office U. S. Fish and Wildlife Service, Washington 25, D. C.

UNITED STATES OF AMERICA

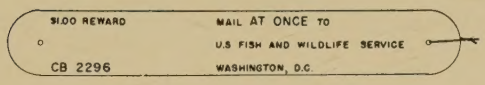
Marking Institution Chesapeake Biological Laboratory.

Type Small plastic (nitrate) tag, red in colour, with hole at each end.

Legend: *Front* $1.00 REWARD, MAIL AT ONCE TO U.S. FISH AND WILDLIFE SERVICE, WASHINGTON, D.C.
CB and number.

Back STATE WHEN AND WHERE CAUGHT OR WHEN AND FROM WHOM PURCHASED.

Figure



Use **Blue Crab** (*Callinectes sapidus*).

Adults: placed saddle fashion on carapace with stainless steel wire twisted around lateral spines.

Juveniles are tagged at suture line below left lateral spine with fine flexible suture wire. The tag is merely tied on.

Scale of Reward For tags and information $1.00

Reception Office Through Fish and Wildlife Service to Chesapeake Biological Laboratory, Solomons, Maryland.

Recent Publications of the International Council:

RAPPORTS ET PROCÈS-VERBAUX.

Vol. No. 133: Rapport. T. Braarud, K. Ringdal Gaarder & Jul. Grøntved: The Phytoplankton of the North Sea and adjacent Waters in May 1948. Avril 1953. Kr. 18.00.

Vol. No. 134: Procès-Verbaux (Sept./Oct.—1952). Rapport Administratif (1951). Avril 1953. Kr. 16.00.

ANNALES BIOLOGIQUES.

Vol. No. VIII: 1951. Décembre 1952. Kr. 30.00.
Vol. No. IX: 1952. In print.

BULLETIN HYDROGRAPHIQUE pour l'année 1948. Janvier 1952. Kr. 25.00.
pour l'année 1949. In preparation.

BULLETIN STATISTIQUE pour l'année 1949. Septembre 1952. Kr. 8.00.
pour l'année 1950. Avril 1953. Kr. 8.00.

FICHES D'IDENTIFICATION DU ZOOPLANCTON.

Nos. 1—17. Mai 1949. Kr. 10.00.
Nos. 18—29. Novembre 1950. Kr. 10.00.
Nos. 30—40. Septembre 1951. Kr. 12.00.
Nos. 41—49. Août 1952. Kr. 12.00.

HERRING ATLAS. — Fisheries of the North-Eastern Atlantic (Fishing Ground, Landing Ports and Quality). Octobre 1950. Kr. 32.00.

SYNOPTIC HYDROGRAPHIC CHARTS. Issued monthly: charts for July 1952 up to and including May 1953 have appeared.
Annual subscription, Kr. 90.00.

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A/S L. IHRICH COPENHAGUE